Senter for forskningsdrevet innovasjon

SMART MARITIME

ANNUAL REPORT 2017

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Senter for forskningsdrevet innovasjon

NORWEGIAN CENTRE FOR IMPROVED ENERGY EFFICIENCY AND REDUCED HARMFUL EMISSIONS FROM SHIP

Photo: Havyard Group.

SUMMARY OF 2017

SKS SINNI. Photo: Mastership/Kristian Gerhard Jebsen Skipsrederi.

SUMMARY OF 2017

The SFI Smart Maritime is dedicated to improving energy efficiency and reducing harmful emissions from ships. With particular focus on the Norwegian Maritime Industry, our mission is to provide our partners with technologies, tools and capabilities for effective identification, assessment and verification of performance optimization solutions. The research focus is on technological solutions within hydrodynamics (hull and propellers) and machinery system (energy optimization, exhaust emissions and fuels).

2017 has been an active and productive year at SFI Smart Maritime, with high activity and an increasing number and variety of deliverables. The dialog between the research team and industry participants is very constructive.

Today Smart Maritime works as a relatively important meeting place and cooperation platform within energy efficiency and environment-friendly shipping.

In addition, the Centre has served as a springboard for new initiatives and further cooperation.

In 2017 the SFI has focused on maintaining the balance between long-term scientific research and more short-term applied research and value creation for industry partners. Direct and regular cooperation has contributed to a first version of a tool for simulation-based design, but also the use of ship operators' own fleet as test case or lab.

The activity list in Smart Maritime has been further sharpened, with effort put on more integration among the various disciplines (Work Packages, WP). This has been achieved through a common project – *SP7 Simulation based concept design* – that takes input from each discipline by integrating models developed in each WP into a common platform.

Communication and documentation have also improved. Smart Maritime offers now Webinars that contribute to more scientific discussion between research team and industry partners. Furthermore, the dialog between the SFI Management and Board is open and constructive.

Two Network meetings were arranged: in March at Rolls-Royce Marine in Ålesund and in October in Værnes hosted by SINTEF Ocean, gathering around 50 participants each time. These have been important meeting places and have contributed to active participation from SFI partners.

In 2017, the Centre launched a discussion about innovation potential of Smart Maritime. This is a item on the priority list for 2018, which first step is a patent landscape analysis currently being carried out by the Norwegian Industrial Property Office.

The involvement and participation of industry partners is crucial for ensuring value creation for the Norwegian maritime industry. This is another priority point for 2018; the SFI management will work systematically to ensure that all competences and opinions among the Consortium come to light and contribute in refining the Centre's strategy.

Highlights from 2017

The main scientific achievements are presented in the section "Scientific activities and results" on page 51.

These include:

- Potential for GHG reduction from shipping
- Prediction of added resistance due to waves
- Steering losses
- Marine hybrid power/propulsion systems
- Design study of the hybrid power/propulsion system for deep sea shipping
- LNG fuelled vessels and methane slip
- Abatement technologies
- Innovative ship concepts for deep-sea operators developed with the GYMIR tool
- Validation study of the GYMIR virtual testing workbench
- Maritime Transport Environmental Assessment Model (MariTEAM)

Photo: Wallenius Wilhelmsen Logistics.

NORSK SAMMENDRAG

SINTEF Ocean er vertsinstitusjon for SFI Smart Maritime, som ble åpnet i 2015, med støtte fra Forskningsrådet under SFI-ordningen (Sentre for forskningsdrevet innovasjon). Senteret fokuserer på forbedring av energieffektivitet og reduksjon av skadelige utslipp fra skip. Vi søker å forbedre konkurransekraften til Norsk Maritime industri gjennom ny teknologi, verktøy og effektive løsninger på industriens utfordringer. Vi vil finne svar på hvordan det er mulig å oppnå økt energieffektivitet og reduserte utslipp innen den maritime sektoren, også med bruk av konvensjonell teknologi og drivstoff.

De tekniske forskningsområdene er innenfor hydrodynamikk (skrog og propell) og fremdriftsmaskineri (energioptimalisering, avgassutslipp og drivstoff), og det legges vekt på betrakting av skipet som system. Smart Maritime jobber med utvikling av systemorienterte verktøy som analyserer effekten av energieffektiviserende løsninger og tiltak for skrog og propell, kraftsystemer og drivstoff under realistiske fullskalaforhold.

Målet er å kunne simulere og optimalisere skipet numerisk før det bygges. Senteret jobber med referanseskip som i reell drift og med god instrumentering vil gi tilbakekobling til de numeriske modeller for justering og videreutvikling. Smart Maritimes verktøykasse suppleres med en livssyklus modell for analyse av miljøpåvirkning av nye tiltak på skips- og flåtenivå.

Blant bedriftspartnerne er toneangivende bedrifter som Rolls Royce Marine, Bergen Engines, Vard Design, Havyard Group, ABB, SIEMENS, Norwegian Electric Systems, Jotun, Wärtsilä Moss og DNV GL, samt viktige brukere som Wallenius Wilhelmsen Logistics, Solvang, Grieg Star, Kristian Gerhard Jebsen Skipsrederi og Norges Rederiforbund. I tillegg er sentrale aktører som Kystrederiene og Sjøfartsdirektoratet partnere i SFI Smart Maritime.

VISION AND OBJECTIVES

"Smart Maritime is a Centre for Research-based Innovation (SFI) for higher energy efficiency and lower harmful emissions from ships".

Vision of The Fjords. Power and Propulsion technology from ABB.
Photo: Sverre Hjørnevik/The Fjords.

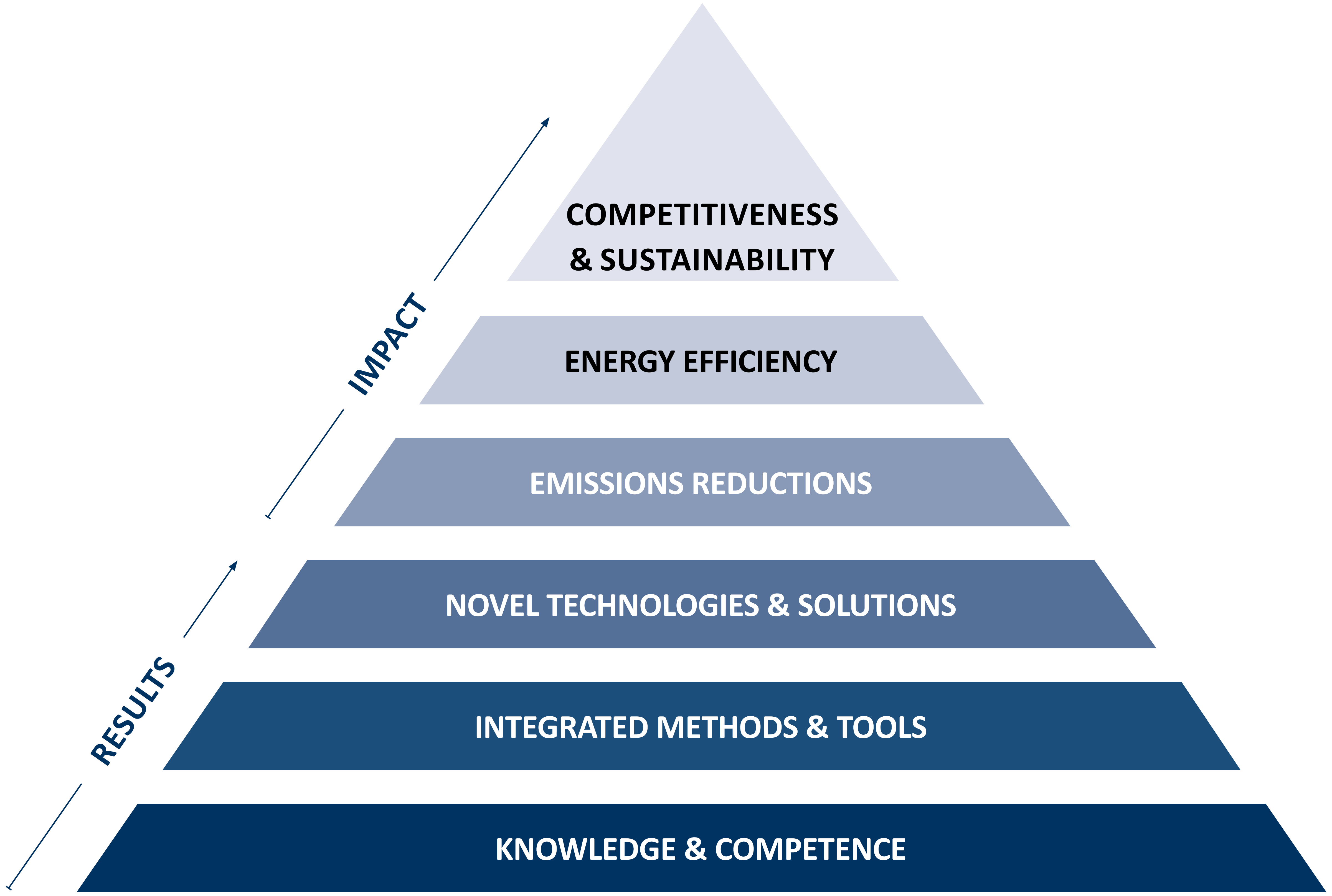
Our vision is greening maritime transport, and by that enabling the Norwegian maritime cluster to be world leading in environmentally friendly shipping by 2025. This position will be gained through innovative use, improvement and combination of technologies, which are cost-, energy- and emission efficient, but also will strenghenthe competitiveness of the Norwegian maritime industry.

Our mission is to provide the Norwegian maritime sector with knowledge, methods and tools for effective identification and assessment of solutions and technologies.

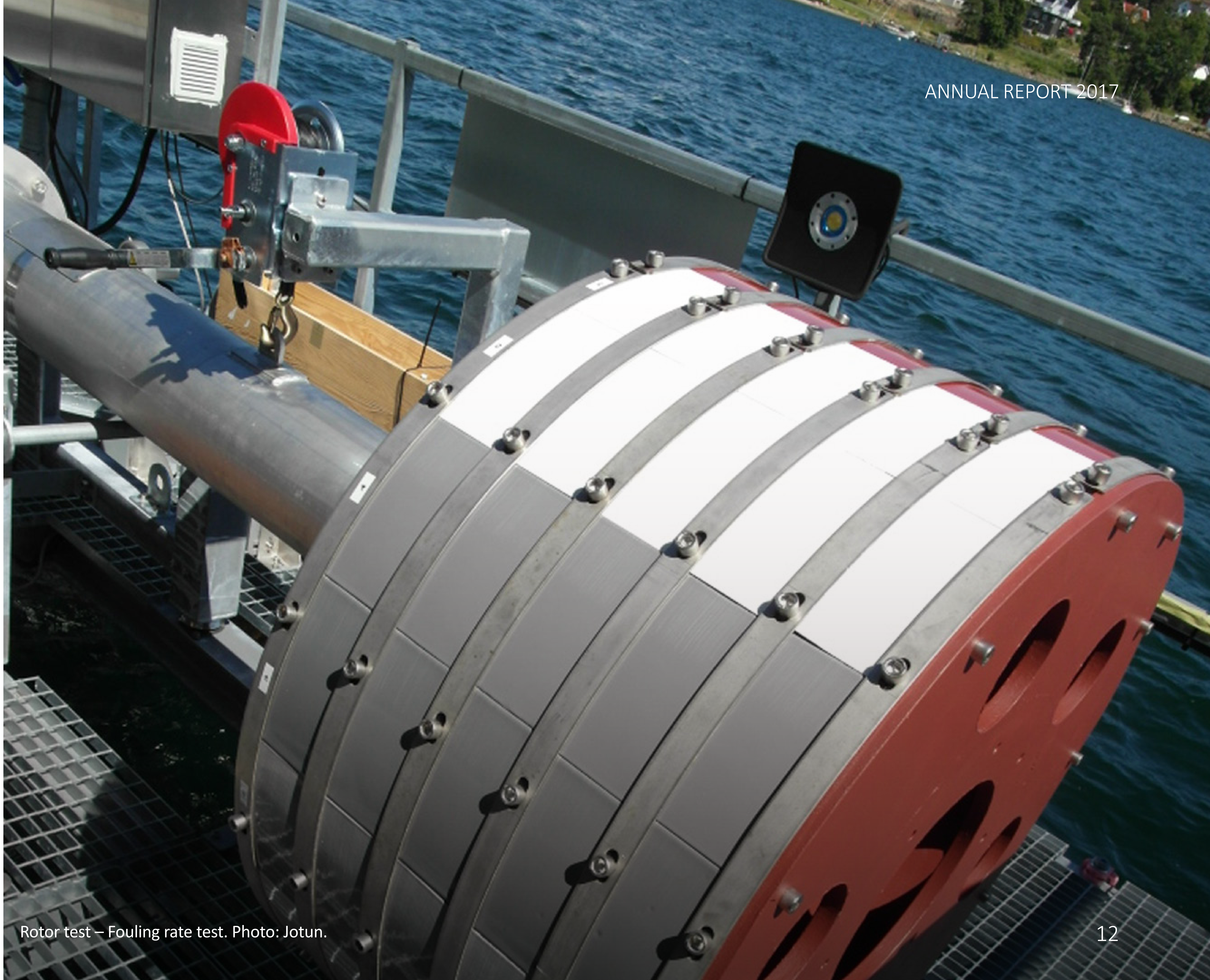
Photo: Sjøfartsdirektoratet.

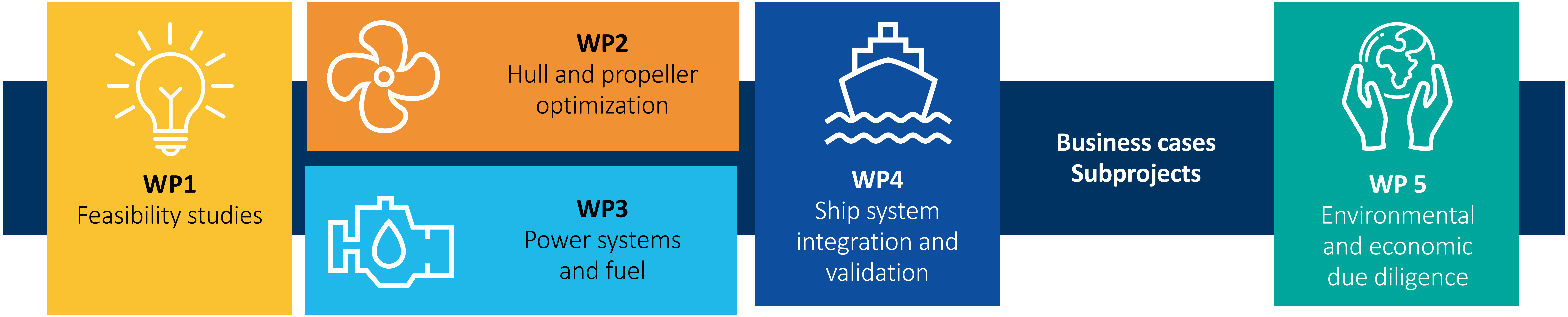
The expected outcomes include:

1. More efficient and accurate early stage assessment of new ship designs.
2. Introduce new validation methods, such as correlating data from real-life conditions with simulation- and experimental data.
3. More accurate predictions of fuel consumption and emissions from alternative hull, propulsion and power system configurations and operational profiles.
4. Improved optimization of ship performance vs. cost profile at various operational profiles and sea states.
5. Improved methods and tools for cost and fuel optimization – on unit level and on fleet level. The Centre collaborates closely with global industry players, national and international research communities and maritime networks.



RESEARCH STRATEGY AND PLAN


Rotor test – Fouling rate test. Photo: Jotun.



To fulfil a vision of environmental and energy efficient maritime transport, SFI Smart Maritime will provide models, methods and tools for improved design, assessment and validation of innovative technologies and solutions. Doing so, the Centre aims at strenghening the competitiveness of the Norwegian Maritime industry.

During its 8-year period, the SFI Smart Maritime will finance 9 PhDs and 8 Postdocs.

Research activity is divided into five work packages (WP). These WP follow a concept developmentprocess: WP1 produces feasibility studies to screen the most promising options for energy and emissions reductions. These are further explored and tested in WP2 and WP3. Thereafter WP4 offers a ship system integration platform based on models developed in WP2 and WP3, and used to validate solutions and technologies through simulation of ship performance. Finally, WP5 completes the concept development process by providing environmental and economic due diligence of concepts and solutions at ship and fleet level.

WORK PACKAGES:

WP1:
Feasibility studies

WP2:
Hull and propeller optimization

WP3:
Power systems and fuel

WP4:
Ship system integration and validation

WP5:
Environmental and economic due diligence

Photo: Havyard Group.

WP1: Feasibility studies

Objective

Develop assessment model and method for effective investigation of alternative designs at an early stage. Test and validate through series of feasibility studies.

Research need and background:

There is a lack of assessment methods and tools to enable comparison of alternative designs at the feasibility stage of the design process. Current studies and state-of-the-art design practice regarding concept, speed and capability tends to be based on marginal improvements of existing designs and solutions instead of challenging todays practice. One explanation is that most vessels for the merchant fleet have been built by shipyards according to quite standardized designs to minimize building cost while more specialized vessels generally have been improvements and amendments of existing designs.

Research tasks

Feasibility studies method & tool	GHG emissions reduction potential	Feasibility studies (cases)

WP2: Hull and propeller optimization

Objective

Identify potential for energy savings by means of hull and propulsion optimization, and introduce novel approaches to improve efficiency.

Research need and background:

Currently, most merchant vessels are designed for optimum performance in calm water. There is an increasing understanding of the impotance of including sea-keeping and manoeuvring-related aspects, but it has not found its way into practical design work yet. The tools currently used in design of offshore vessels have a potential for being applied in the design of merchant vessels. Despite this, design for a balanced set of operational conditions is still at the development stage even for offshore vessels. Hydrodynamic performance of ships and propulsion systems, with special emphasis on operation in waves, are specially addressed in WP2.

Research tasks

Calm water performance	Energy-saving devices	Novel propulsion system	Operations in waves
Friction-reduction Novel overall-design (main dim.)	Effect of waves and off-design operation Evaluation of in-service performance	Wave-foil propulsion Optimization of sail-assisted merchant vessels	Speed loss Interaction with engine Operational profile Above-water geom.

WP3: Power systems and fuel

Objective

Improve current designs and explore novel technologies, systems and solutions for energy efficient low emission propulsion power systems.

Research need and background:

Reducing fuel consumption and harmful emissions for different vessel types at different operation profiles and modes to comply with current and future IMO legislations is currently the main challenge for maritime transport.

Traditionally the power solutions for seagoing vessels have been designed to ensure that the vessels have the required power to be seaworthy in rough weather and to achieve its desired design speed utilizing 85 % of its installed power resources on calm water.

Research tasks

Power system optimization	Combustion engine process	Waste Heat Recovery	Hybrid systems
Modeling and simulation of power components and systems Variable load cycles	Advanced combustion control Alternative fuels (LNG, biofuels, alcohols, hydrogen) Exhaust gas cleaning	Combined cycles and turbo-compound systems Thermoelectric power generation Heat mangement	Hybrid concepts Energy storage systems (batteries) Energy converters and transmissions Optimal control

WP4: Ship System Integration and Validation

Objective

Enable performance evaluation and benchmarking of designs on a ship system level by combin-ing monitoring data and simulations in a frame-work where component and subsystem models can be combined in a full ship system. Validate the results through laboratory and full-scale tests.

Research need and background:

The research activity in WP 4 will consider how to technically integrate the components and sub-system developed in WP 2 and 3 in one simulation framework where the full complexity of the future operational profile of the vessels is considered. This holistic system-centered ship design process will enable accurate performance assessment of full ship systems in realistic operational conditions, and assessment of effects of energy efficiency improving measures. In addition, continuous optimization of these systems can be achieved by the combination of real-time monitoring and appropriate system simulations.

Research tasks

Simulation framework	Virtual ship design testing	Simulator validation
Open framework connecting physical domains and modeling regimes Support of Discrete-event simulation and Time-domain simulation Model library database	Methods for assessing system performance against operational profiles KPI's for benchmarking of alternative designs Ship configuration and scenario management	Methodologies for collection, filtering and use of full-scale measurement data Validate and calibate the ship system simulations

WP5: Environmental and Economic Due Diligence

Objective

Systematically assess the environmental and economic performance parameters of different ship and shipping system designs.

Research need and background:

Both maritime trade and international transport have increased at tremendous rates in the past decades. Maritime transport is estimated to contribute 3.3 % to the global anthropogenic CO_2 emissions, and the environmental consequences of increased trade are an important factor in the current climate debate. There is a need for detailed harmonized environmental and economic costs assessment of current and novel ship designs. In addition, there is a lack ofgood approaches for integration of such assessments with ship designand engineering workflows. WP5 will integrate state of the art methods for detailed environmental and economic analyses.

Research tasks

MariTEAM	Spatial-temporal impact	Life cycle assessment	Scenario analysis
Software development Theory-guided big data analytics	Environmental impacts located in time and space	Environmental impacts throughout supply chain and service life time established	Fleet and route development Comparisons of technology option

ORGANIZATION

NKT Victoria. Hybrid propulsion and energy storage system from ABB. Photo: Fuglefjellet/NKT.

ORGANIZATION

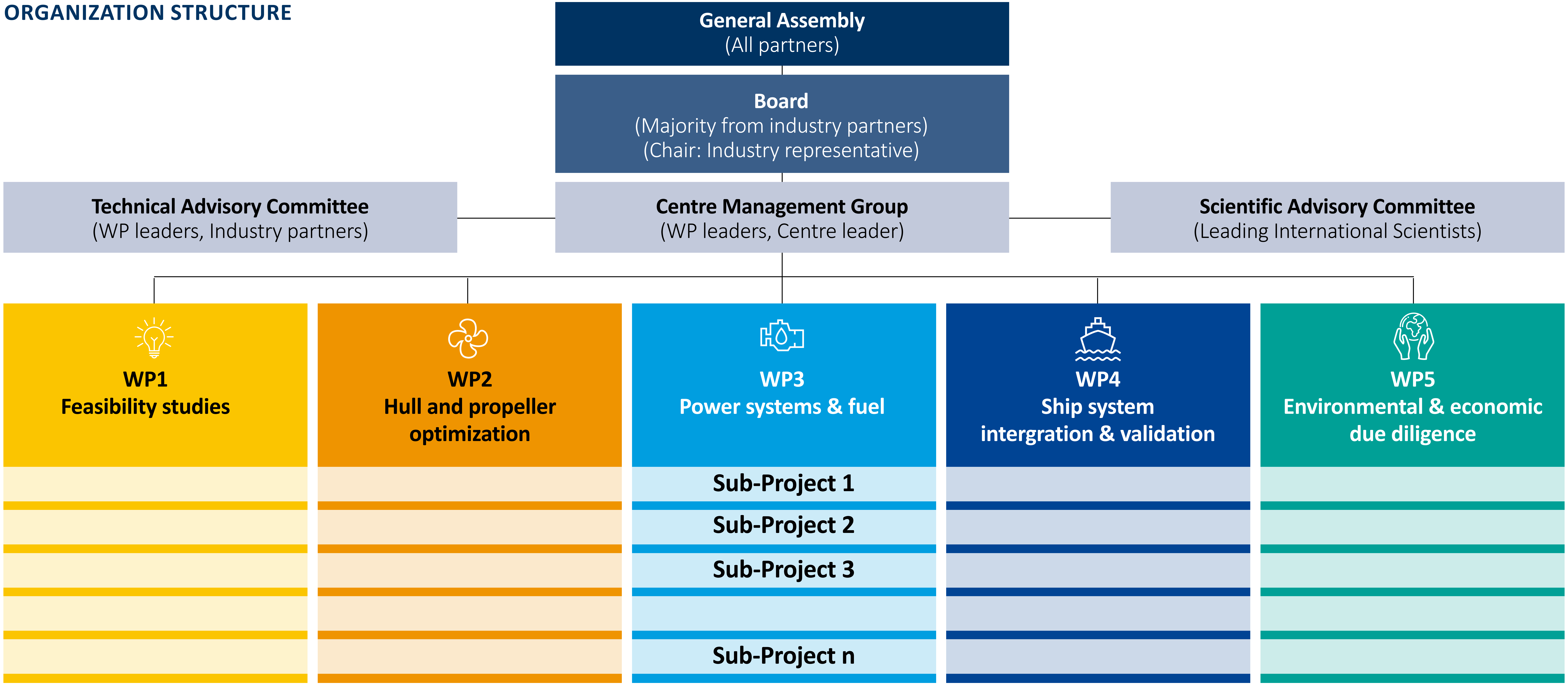
The Centre is using a matrix organization where the long-term research with the PhD programs performed in Work Packages (WP). Across of the WP's are Sub-Projects (SP) involving two WP's as a minimum. These Sub-Projects are shorter term activity defined and carried out in direct collaboraiton with industry partners.

General assembly consist of all partners and a Centre Board with seven members, industry partners in majority. The Centre management team consist of the WP leaders, Centre Director and a Deputy Centre Director.

The Technical Advisory Committee (TAC) is formed to create a meeting place for all partners in the Centre to discuss and suggest activities in the WP's and SP's. Its role is to advise the Centre Management on prioritization of R&D activities to be conducted within Smart Maritime. The TAC is gathered together twice a year at the biannual Network Meetings.

The Scientific Advisory Committee consists of leading international capacities auditing and advising the research activities in the Centre.

ORGANIZATION STRUCTURE



Board Members	Affiliation
Jan Øivind Svardal *(Chairman)*	Grieg Star
Jan Fredrik Hansen	ABB
Per Ingeberg	Rolls-Royce Marine
Kjell Morten Urke	Vard Design
Lars Dessen	Wallenius Wilhelmsen Logistics
Beate Kvamstad-Lervold	SINTEF Ocean
Bjørn Egil Asbjørnslett	NTNU
Sigurd Falch (observer)	Norwegian Research Council

General Assembly Chairman	Affiliation
Stig-Olav Settemsdal	Siemens

Industry Coordinator	Affiliation
Roar Fanebust	Grieg Star

BOARD MEMBERS


Jan Øivind Svardal


Jan Fredrik Hansen


Per Ingeberg


Kjell Morten Urke


Lars Dessen


Beate Kvamstad-Lervold


Bjørn Egil Asbjørnslett


Sigurd Falch


Stig-Olav Settemsdal


Road Fanebust

SMART MARITIME

BOARD MEETINGS 2017

June: Review of ongoing activities

August: Strategy meeting with Centre Management team

November: Planning and budget 2018,
preparation for General Assembly 2017

Photos: Snøfugl.

Centre Management Group	Affiliation	Role and responsibility
Per Magne Einang	SINTEF Ocean	Centre Director
Anders Valland	SINTEF Ocean	Deputy Director
Elizabeth Lindstad	SINTEF Ocean	WP1 Feasibility studies
Sverre Steen & Sverre Anders Alterskjær	NTNU/SINTEF Ocean	WP2 Hull and Propeller
Sergey Ushakov	NTNU	WP3 Power systems and Fuel
Trond Johnsen	SINTEF Ocean	WP4 Ship system Integration
Anders Strømman & Anna Ringvold	NTNU	WP5 Environment and economy

Centre administration	Affiliation	Role and responsibility
Jan Andre Almåsbakk	SINTEF Ocean	Controller
Inger Gudmundsen	SINTEF Ocean	Document control and Web
Agathe Rialland	SINTEF Ocean	Administrative Coordinator

CENTRE MANAGEMENT GROUP AND CENTRE ADMINISTRATIONS

Per Magne Einang

Anders Valland

Elizabeth Lindstad

Sverre Steen

Sverre Anders Alterskjær

Sergey Ushakov

Trond Johnsen

Anders Strømman

Anna Ringvold

Jan Andre Almåsbakk

Inger Gudmundsen

Agathe Rialland

Scientific Advisory Committee	Affiliation	Focus area
Professor Karin Anderson	Chalmers University of Technology, Gothenburg	WP 5
Professor Rickard Benzow	Chalmers University of Technology, Gothenburg	WP 2
Professor Harilaos Psaraftis	DTU – Technical University of Denmark	WP 4
Professor Osman Turan	Strathclyde University	WP 1
Professor Friedrich Wirz	TU Hamburg	WP 3

MEETING THE SCIENTIFIC ADVISORY COMMITTEE

Photos: Rialland.

PARTNERS

SINTEF Ocean hosts the Centre in collaboration with research partners NTNU and NTNU Aalesund. The industry partners, together forming the Technical Advisory Committee, cover major parts of the maritime value chain: ship system suppliers, ship designers, ship owners and stakeholder groups.

These partners are involved in scientific activity through business cases and subproject activity across the WPs.

Hurtigruten – Hybrid Propulsion. Photo: Rolls-Royce plc.

INDUSTRY PARTNERS

Design, shipbuilding & equipment

Roll-Royce
Bergen Engines
Vard Design AS
Havyard
Norwegian Electric Systems (NES)
ABB
Simens
Jotun
Wärtsilä Moss

Ship operators

WWL
Solvang
Grieg Star
KGJ Skipsrederi

Other partners

DNV GL
Norwegian Shipowner's Association
Norwegian Maritime Directorate
Kystrederiene

RESULTS

Knowhow Technologies
Concepts Solutions

Problem description
Operational experience
Personnel and resources
Infrastructure
(ships & equipment)

SMART MARITIME

SINTEF Ocean

NTNU

Education
Basic/applied research
Maritime experience
Laboratories

International network and customers

International R&D partners

RESEARCH PARTNERS

SINTEF Ocean (host)

NTNU

Department for Maritime Technology

Industrial Ecology Programme

NTNU – Ålesund

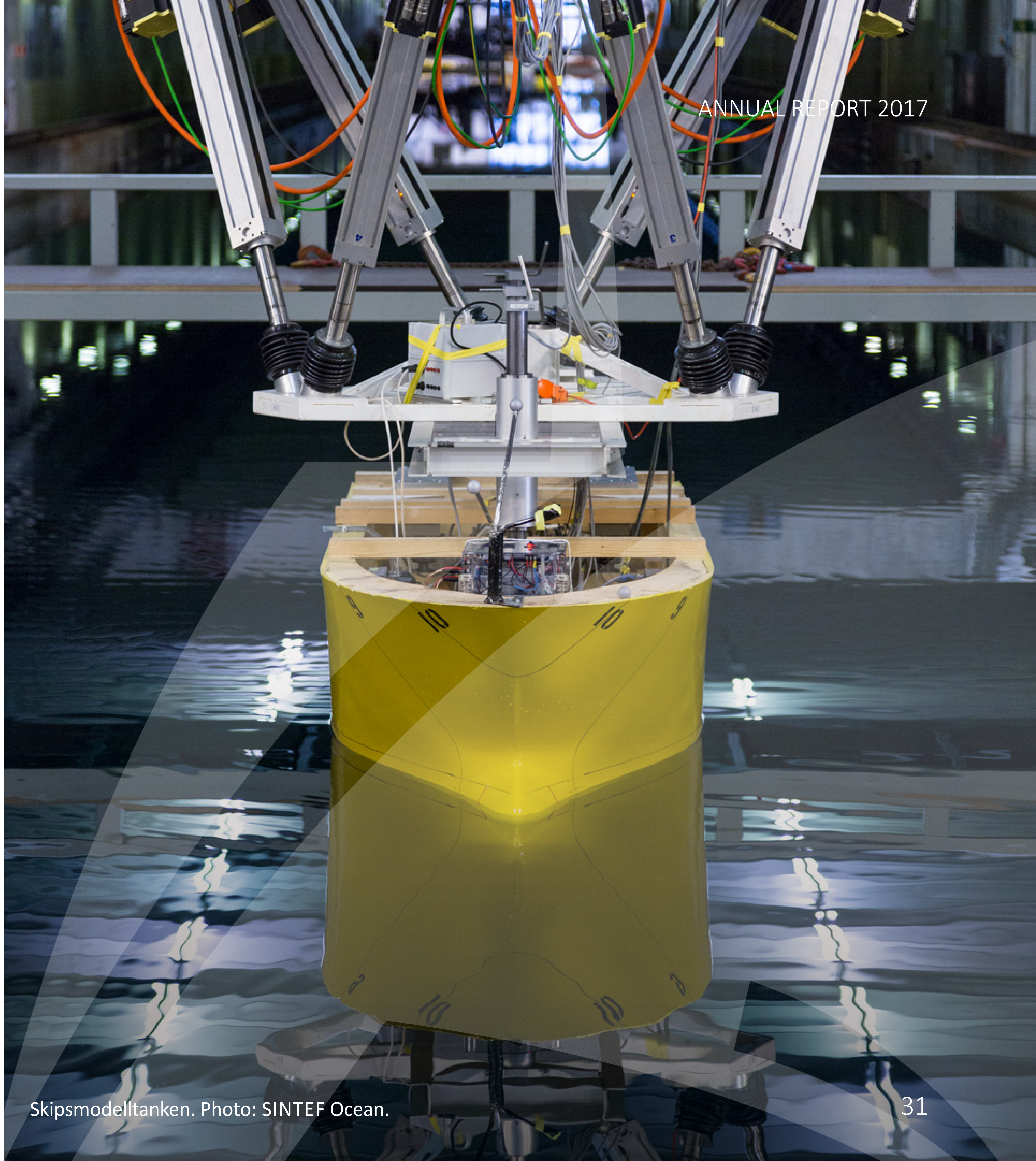
Faculty of Maritime Technology and Operations

OCEAN SPACE CENTRE

SFI Scope aligned with Ocean Space Centre strategy.

SMART MARITIME

NTNU and SINTEF Ocean have developed a joint strategy for Ocean Space Centre where Smart Maritime is one of five strategic areas for research and education. In 2012 SINTEF OCEAN, SINTEF, NTNU and NTNU Aalesund formalized an inter-regional collaboration project with the objective to strengthen the interaction between the Møre maritime cluster and the research and education communities in Trondheim and Ålesund. This work has led to several KPN, IPN and offspring projects that supporting the activities in SFI Smart Maritime and Ocean Space Centre.



Skipsmodelltanken. Photo: SINTEF Ocean.

RESEARCH PARTNERS

SINTEF Ocean (Host institution)
Performs research, development and verification of technological solutions, business and operating concepts for the shipping, marine equipment, ocean energy and petroleum industries.

NTNU – Department of Marine Technology
Educates MSc, PhD and postdoc, and conducts research on marine systems and marine structures.

NTNU – Industrial Ecology Programme
Internationally leading institution within its field and has five authors contributing to the forthcoming WG III assessment report of the IPCC.

NTNU – Department of Ocean Operations and Civil Engineering (Ålesund)
Educates candidates on BSc and MSc level. The Faculty conducts research in the fields of maritime systems and operations.

INDUSTRIAL PARTNERS – SHIP OWNERS

Wallenius Wilhelmsen Logistics ASA
Global logistics company, serving the manufacturing industry with special focus on vehicles, machinery, rail and the energy sector. WWL ASA has a combined fleet of 127 vessels with more than 800,000 CEU capacityulty conducts research in the fields of maritime systems and operations.

Grieg Star AS
Fully integrated shipping company operates a fleet of around 40 vessels transporting parcel cargo, break bulk and dry bulk cargo (30 under ownership).

Solvang ASA
One of the world leading transporters of LPG and petrochemi-cal gases. The fleet consist of 23 vessels – semi-refrigerated/ethylene carriers, LPG ships and VLGC.

Kristian Gerhard Jebsen Skipsrederi AS
KGJS is a fully integrated shipping company involved in tankers, dry cargo and specialized cement vessels over 50 ships under management.

INDUSTRIAL PARTNERS – DESIGN & SHIPBUILDING

Havyard Group ASA

Fully integrated Ship Technology company and deliver products and services within the complete value chain from vessel design to support of vessels in operation. Market segments include Energy, Seafood and Transport.

Rolls-Royce Marine AS

Leading provider of innovative ship designs and systems, and a manufacturer of power and propulsion systems to oil & gas, merchant and naval sectors.

Vard Design AS

Major global shipbuilder of offshore and specialized vessels for offshore oil and gas exploration, production and service.

EQUIPMENT AND SYSTEM SUPPLIERS

ABB AS

Leading manufacturer of electric power and propulsion systems for ships. The product range also includes advisory systems for monitoring operational parameters.

Bergen Engines AS

A subsidiary of Rolls-Royce Power Systems within the Land & Sea Division of Rolls-Royce. Our medium speed gas and liquid fuel engines are supplied for a broad range of power generation applications.

Jotun AS

World's leading provider of paint systems and marine coatings to ship-owners and managers active in the newbuilding and dry-dock and maintenance markets.

Norwegian Electric System AS

NES is an innovative, high-tech electrical company with a focus on diesel electric and hybrid electric systems for the global marine market.

SIEMENS AS avd corporate centre & real estate

Siemens is among the world's leading suppliers of diesel-electric propulsion systems.

Wärtsilä Moss AS

Manufactures advanced inert gas and nitrogen solutions for marine and offshore oil and gas applications. Wärtsilä Norway (parent) delivers solutions for ship machinery, propulsion, automation, ship design, automation systems and liquid cargo solutions.

SERVICE AND STAKEHOLDER ORGANIZATIONS

DNV GL AS
world's largest ship and offshore classification society and a leading technical advisor to the maritime, energy and oil & gas industries.

Kystrederiene
The Coastal Shipowners Association works for promoting sea transport and marine services with focus on innovation and environmental-friendly solutions.

Norges Rederiforbund
Norwegian Shipowners' Association is a non-government organization serving more than 160 companies in the field of Norwegian shipping and offshore activities.

Sjøfartsdirektoratet
The Norwegian Maritime Authority has jurisdiction over ships registered in Norway and foreign ships arriving Norwegian ports.

RESEARCH FACILITIES

The SFI make use of own research facilities (SINTEF OCEAN and NTNU) as well as on-site laboratories from its industry partners.

Dual fuel engines. Photo: Wärtsilä.

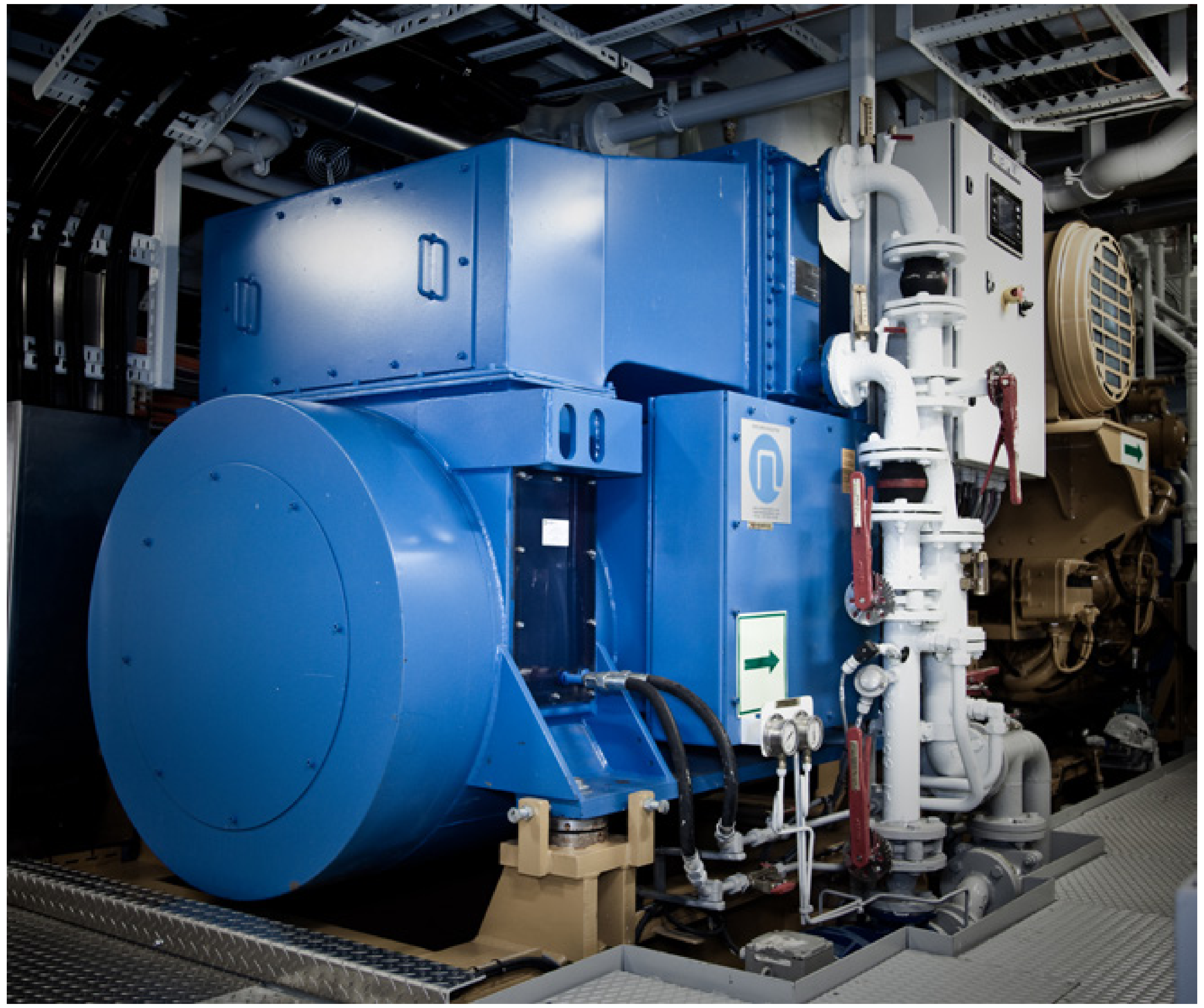


Photo: Norwegian Electric Systems.

ENERGY AND MACHINERY LABORATORY

Amongst the best equipped independent engine laboratories in Scandinavia. Well-developed installations with highly specialized experimental equipment, instrumentation and data-acquisition systems. Full scale medium speed piston engines, complete hybrid propulsion system with batteries for energy storage and combustion rig for ignition and combustion studies.

HYBRID POWER LABORATORY

NTNU's hybrid power laboratory combines power and simulation lab for educational and research purposes. It enables the testing of novel marine power plants.

Energy and Machinery Laboratory. Photo: NTNU/Sintef Ocean.

Hybrid Power Laboratory. Photo: NTNU.

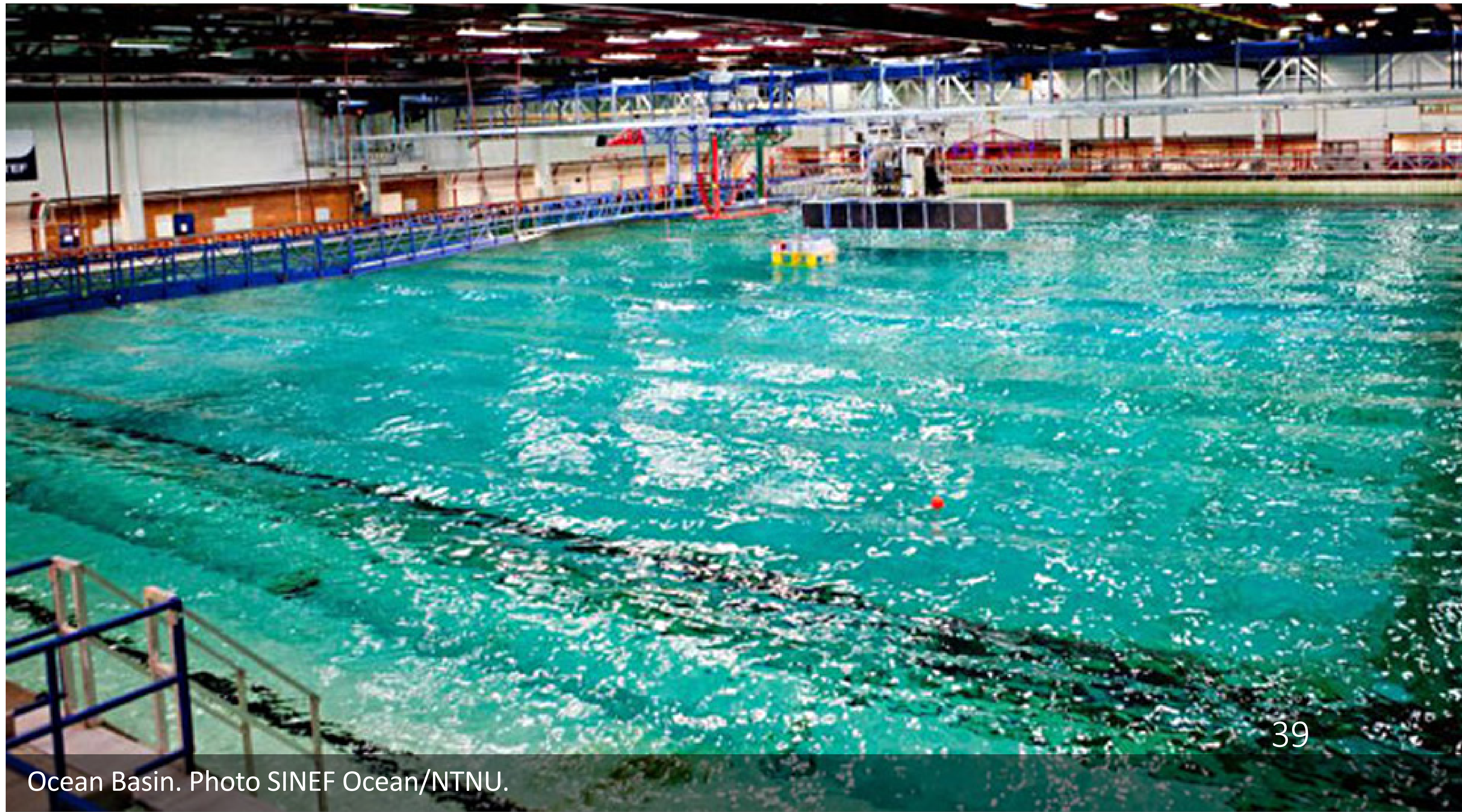
TOWING TANKS

Used for investigation of hydrodynamic performance of ships: resistance, propulsion, seakeeping in head and following seas, and directional stability tests with free running models. The tanks are equipped with two carriages: One for towing up to 10 m/s for traditional calm water tests and a second carriage for seakeeping tests and other tests performed with fixed or free-running models.

Photo: SINTEF Ocean

OCEAN BASIN

Used for basic as well as applied research on marine structures and operations. A total environmental simulation including wind, waves andcurrent offers a unique possibility for testing of models in realistic conditions. With a depth of 10 metres and a water surface of 50 x 80 m, the Ocean Basin Laboratory is an excellent tool for investigation or existing of future challenges within marine technology.



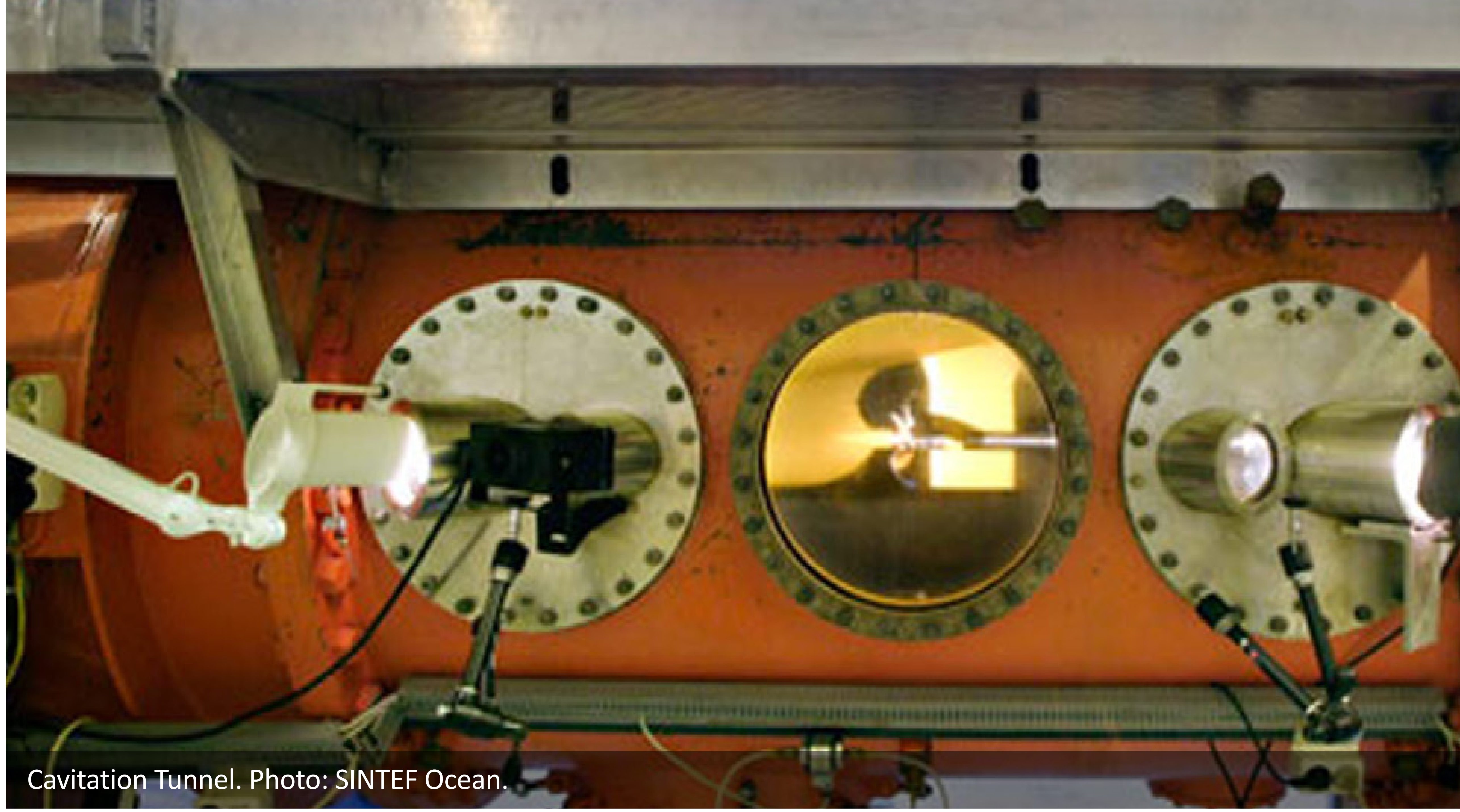
Ocean Basin. Photo SINEF Ocean/NTNU.

CAVITATION TUNNEL

The cavitation tunnel is used to investigate the hydrodynamic performance of different type of ship hulls, propulsors and other hydrodynamic objects. Propeller induced pressure fluctuations andnoise as well as cavitation are investigated by means of measurements and high speed video observation. Propeller shaft and single propeller blade forces and moments can be measured using advanced inhouse developed miniaturized instrumentation, in addition to standard thrust and torque measurements.

CIRCULATING WATER TUNNEL

Test facility dedicated to optical measurement techniques and flow visualization. The tank's measurement section is completely transparent and can be operated either with a free surface or the lid closed.



Cavitation Tunnel. Photo: SINTEF Ocean.

Circulating Water Tunnel. Photo: SINTEF Ocean.

R/V GUNNERUS

The NTNU research vessel R/V Gunnerus is a platform for ocean research, both with respect to technology and life sciences. It has a full diesel-electric propulsion plant, and has recently been upgraded with two novel Rolls-Royce rim-drive permanent magnet azimuthing thrusters. It has the latest Kongsberg DP and motion measurement systems, and it is equipped with Rolls-Royce HeMOS remote monitoring system.

Gunnerus. Photo: Fredrik Skoglund.

CLIPPER HARALD

Clipper Harald (Solvang) A LPG tanker operating at coast of Norway on HFO equipped with Exhaust Gas Scrubber with open loop and wash water cleaning system. EGR (Exhaust Gas Recirculation system) for reduction of NOx emissions.

Clipper Harald. Photo: Solvang.

BERGEN ENGINES LABORATORY

Bergen Engines Laboratory for Gas engine development operating on LNG and equipped with complete exhaust gas emission analysis including PM (Particulate Matter).

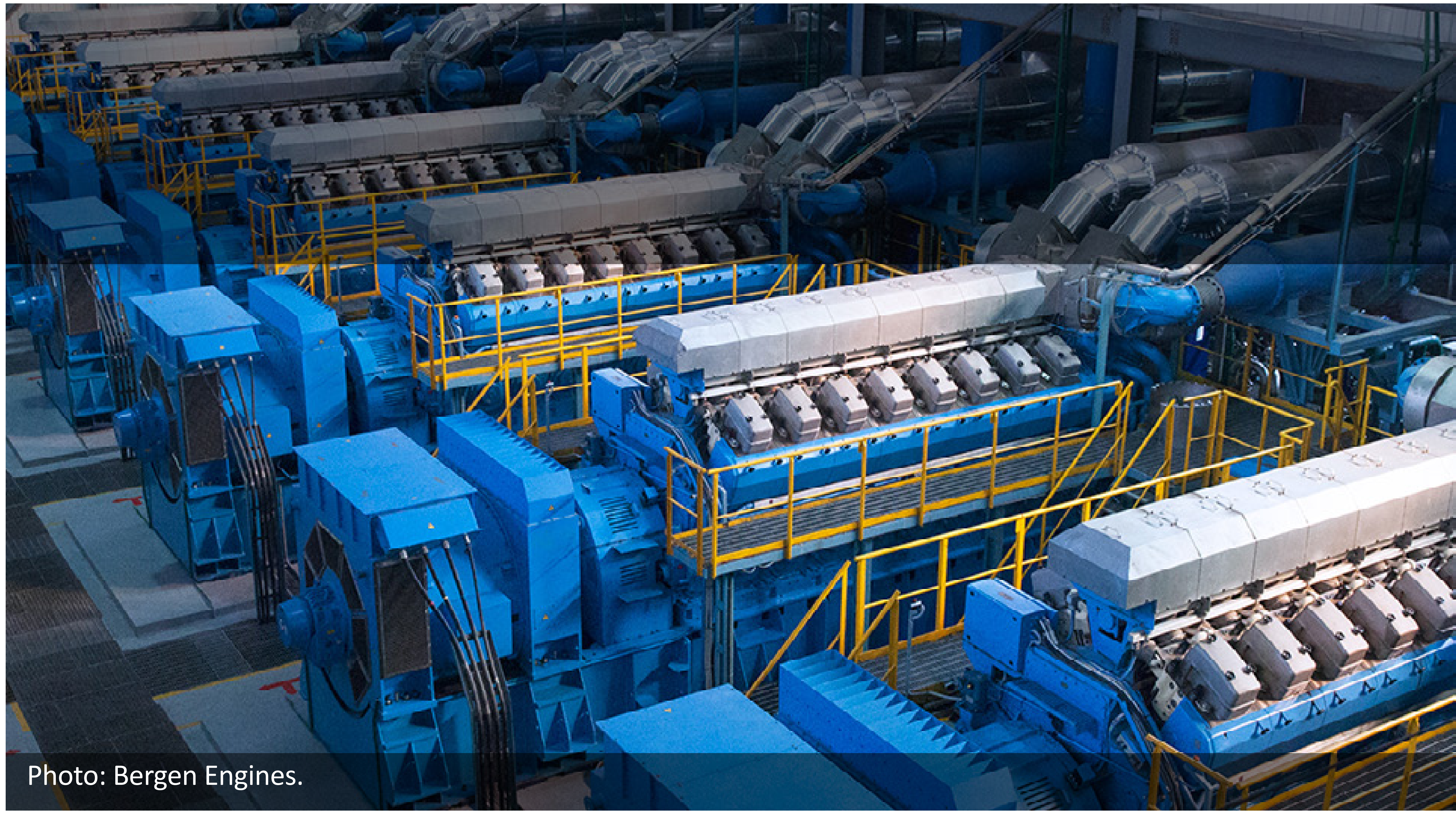


Photo: Bergen Engines.

INTERACTION ACADEMIA – INDUSTRY – RESEARCH

Project cooperations

Smart Maritime enjoys a network of highly motivated industry representatives, striving for knowledge and excellence. Each of the 14 industrial partners is involved in at least one R&D activity in Smart Maritime.

Industry participation includes the following:

- Sharing of operational data, participation in experiments
- Laboratory or test ship made available for research
- Direct involvement in research work
- Cooperation on model and tool development
- Participation at workshops and webinars
- Scientific discussion, knowledge sharing, competence development
- Associated projects, joint initiatives for spin-off projects
- Support to Master theses
- Dissemination, cooperation on scientific publication

Network meetings

Smart Maritime organizes a network meeting twice a year when the research team and the industry partners (functioning as the Technical Advisory Committee) gather for two days. The purpose is to provide a meeting place for the partners to exchange ideas and experience, receive updates and scientific lectures from the research team, discuss new challenges and launch new initiatives, and help prioritize R&D activities.

In 2017, the first network meeting took place in Ålesund, hosted by Rolls-Royce Marine, and focused on scientific updates and gathering needs and expactations from indsutry partners.

The second meeting, in Stjørdal, hosted by SINTEF Ocean, aimed at presenting the achievements from 2017 and together prepare for 2018.

SMART MARITIME

NETWORK MEETINGS, 15–16 MARCH 2017

Host: Rolls-Royce Marine

Place: Ålesund

No participants: 42

Photos: Rialland.

SMART MARITIME

NETWORK MEETING, 17–18 OCTOBER 2017

Host: SINTEF Ocean

Place: Stjørdal

No participants: 48

Photos: Rialland.

WEBINARS

In addition, and to respond to a need expressed by industry partners, Smart Maritime launched Webinars (online meetings) enabling short presentation of one specific topic and scientific discussion with meeting participants. Webinars enable the participations of a wider audience and effective dissemination of scientific activity. The Webinars arranged in 2017 were:

- Hybrid Propulsion System – Design and Application with PTI PTO solutions, lead by Kevin Koo-sup Yum, September 19th.
- LNG-fuelled vessel, lead by Dag Stenersen and Per Magne Einang, June 21st.

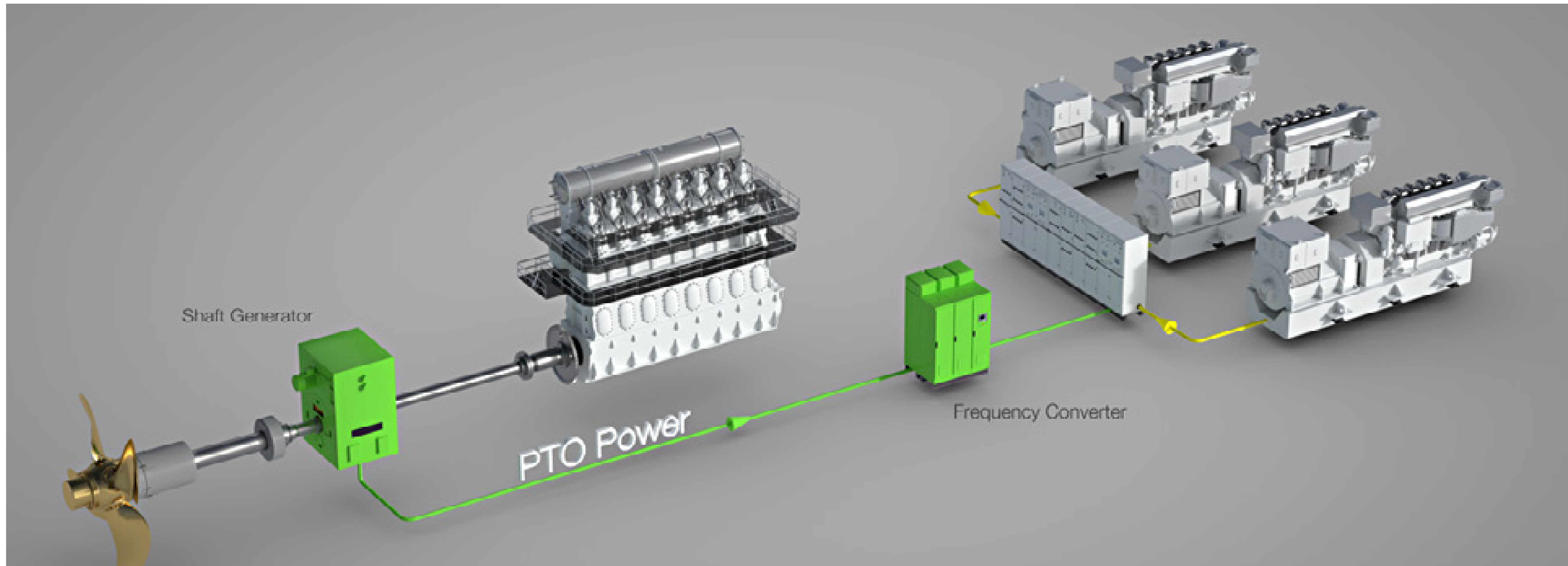


Photo: Wärtsilä.

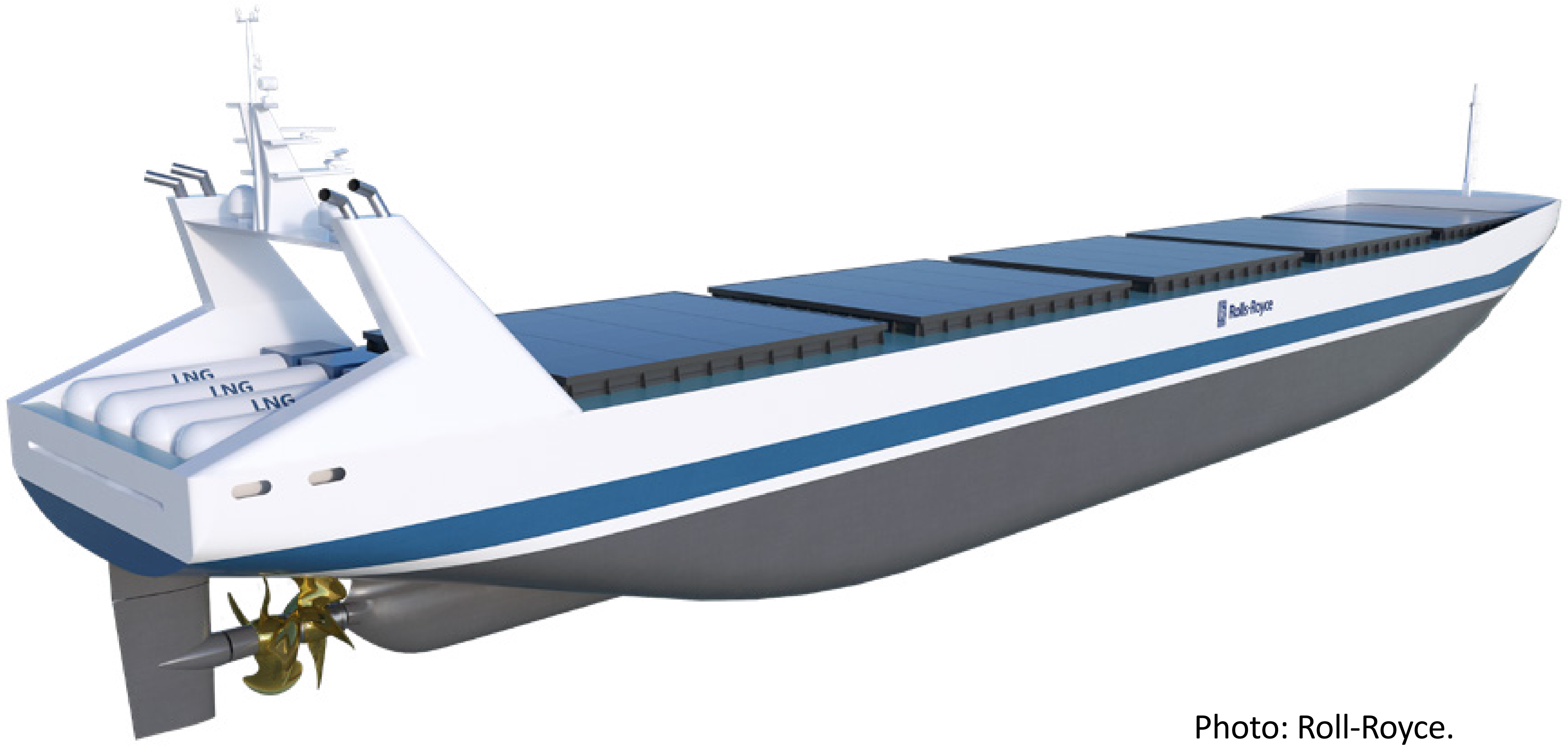


Photo: Roll-Royce.

INDUSTRY COORDINATOR

The Centre's management cooperates with Smart Maritime's industry coordinator in preparation and follow up of meetings with industry, and in the process of yearly planning and prioritization of activities. The purpose of the Coordinator is to be a single point of contact and ensuring that all industry partners' interests are respected. In 2017, Roar Fanebust succeeded to Gunnar Gamlem as coordinator for Smart Maritime's Technical Advisory Committee.

Gunnar Gamlem
Coordinator 2016-2017

Road Fanebust
Coordinator from august 2017

SCIENTIFIC ACTIVITIES AND RESULTS 2017

Trimaran – WalkToWork. Photo: VARD.

ACTIVITY 2017

	WP1 **Feasibility studies**	**WP2** **Hull and propeller optimization**	**WP3** **Power systems & fuel**	**WP4** **Ship system intergration & validation**	**WP5** **Environmental & economic due diligence**
	FCA methodology Potential energy efficiency and emissions reduction Feasibility studies – cases	Calm water performance Energy Saving Devices Novel propulsion systems Operations in water	Power systems optimization Combustion engine process Waste heat recovery Hybrid systems	Integration of power system sub-models Virtual ship design Simulation framework	Parameterized lifecycle model Fleet level assessment Inventory database
SP1 – Alternative fuels and abatements technology			**Performance meansuring and analysis**		**LCA Well-to-propell**
SP7 – Simulation-based concept design (building on SP 2, 3, 4, – 2016)	**Functional concept assessment methodology**	**Hydrodynamic models**	**Power system models**	**GYMIR – performance simulation**	**MariTEAM – environmental assessment**

Case 1 – Deepsea Vessel Shipowners perspective, lower detail level, quicker study

Case 2 – Offshore Vessel Ship designers perspective, higher detail, more study time

AD HOC ACTIVITIES: WEBINARS, THEMATIC / LITTERATURE REVIEW, WORKSHOPS, MSc these

Main projects and activity carried out in 2017. Horizontally are the Sub-Projects conducted in collaboration with industry partners. Vertically are the main scientifc activities conducted at WP level.

SCIENTIFIC RESULTS

2017 can be summarised as a period of consolidation of research activity and topics, coordination among research disciplines (Work Packages), and increased collaboration between research and industryrepresentatives.

The fruits of these efforts include:

- 6 publications in scientific journals
- 14 conference papers or presentation
- 3 scientific reports
- 12 MSc theses
- 2 case studies (SP7)
- 2 field works / emission measurements (SP1)
- 3 simulation and analysis tools (a. o. GYMIR, MariTEAM)
- 1 spin-off new collaboration initiative to start in 2018
- 1 associated research project to start in 2018

The main scientific achievements from 2017 are presented in the following pages. All these results have been made possible by the constellation of competence available at the Centre.

POTENTIAL FOR GHG REDUCTION FROM SHIPPING

Contact: Elizabeth Lindstad, SINTEF Ocean

The environmental consequences of increased international trade and transport have become important because of the current climate challenge. In a business-as-usual (BAU) scenario, future emissions are expected to increase by 150 %–250 % over the period 2012–2050.

Figure 1 shows shipping emissions up to 2050 for the 16 different scenarios developed in the third IMO GHG study (Smith et al 2015). In best case for climate mitigation, emissions will stabilize and in worst case they will increase by 250 %. These emission growth prospects are opposite to what is required to reach a climate targets by 2100. Nevertheless, it is a controversial issue how the annual greenhouse gas reductions shall be taken across sectors. Given a scenario where all sectors accept the same percentage reductions, the total shipping emissions in 2050 may be no more than 15%–50 % of current levels. In unit terms to reach the 1.5–2 degrees target, the CO_2 emissions must be reduced from approximately 20 – 25 gram in 2007 to 4 gram or less of CO_2 per ton-nautical mile in 2050, i.e. a 80–85 % reduction.

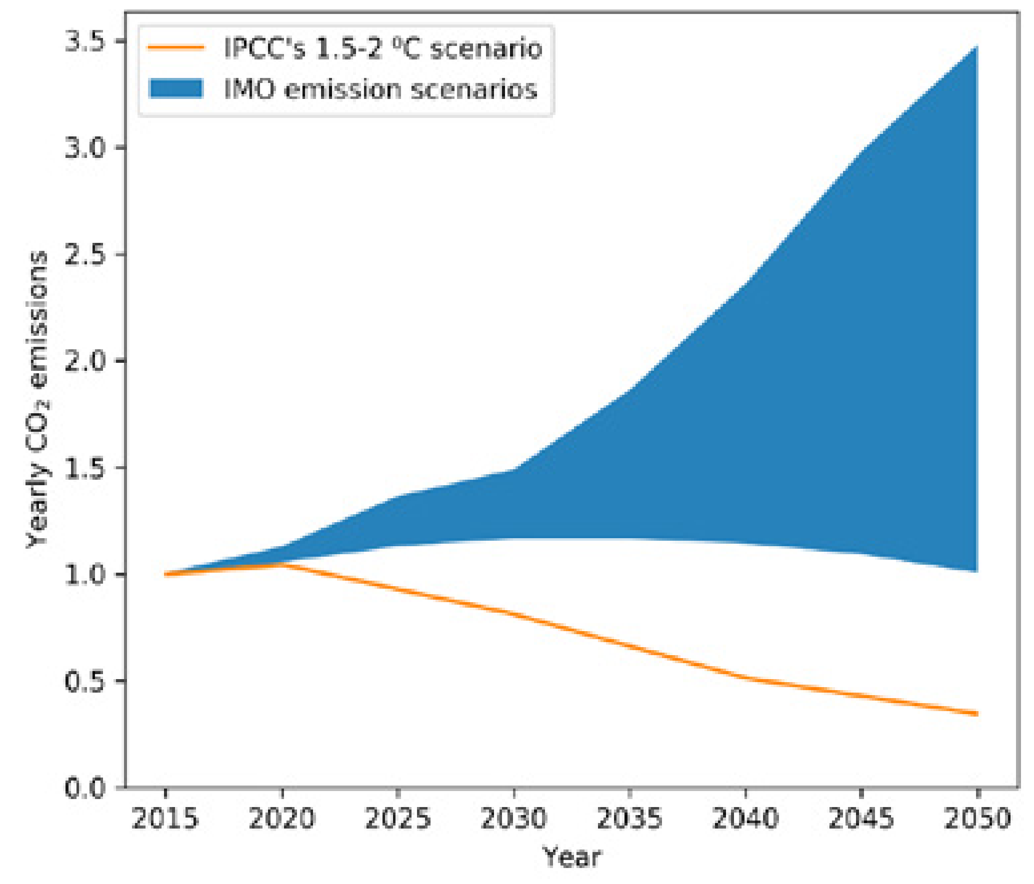


Figure 1: Scenarios for Global Shipping emission. Lindstad et al., (2018) based on IPCC (2013); Smith et al. (2014).

Bouman et al 2017 presents the results of a review of nearly 150 studies, to provide a comprehensive overview of the CO_2 emissions reduction potentials and measures published in literature.

The study grouped the measures in five main categories: *hull design, power and propulsion, alternative fuels, alternative energy sources, and operations.* Figure 2 shows the CO_2 reduction potential for each of the 22 measures identified. For each, a solid bar indicates the typical reduction potential area, i.e. from 1st to 3rd quartile of the dataset, and a thin line indicates the whole spread. In addition, the data points are shown by a small circle.

We observe a large range in emission reduction potential per measure reported by the individual studies. Some of the variability can be explained by differences in assumptions and benchmarks across the selected studies, but it also indicates large uncertainty as to the effectivity of reported reduction potentials.

If all options depicted in Figure 2 could have been combined, which is a highly hypothetical exercise, the emission reductions would be over 99 % based on 3rd quartile values. A more likely feasible combination would however be: Vessel size; Hull shape; Ballast water reduction; Hull coating; Hybrid power/propulsion; Propulsion efficiency devices; Speed optimization; Weather routing and Trim/Draft optimization.

Assuming relatively large independence between the individual measures, combining these options can lead to emission reductions of 80 % based on 3rd quartile values, 59 % based on the median, and 34% based on 1st quartile values.

The review indicates that it is possible to reduce emissions by a factor of 4 to 6 per freight unit transported, based on current technologies and by 2050 if policies and regulations are focused on achieving these reductions.

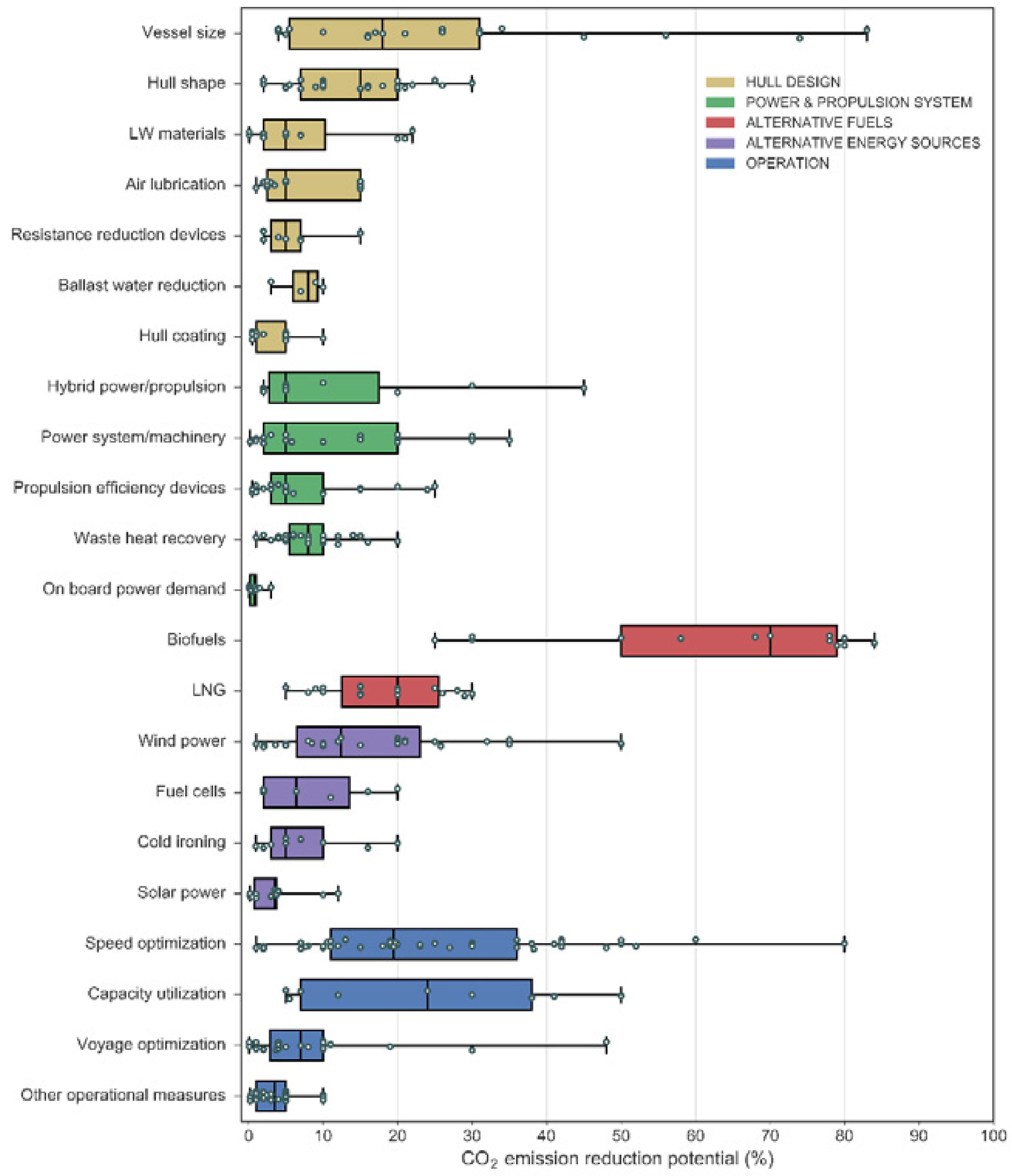


Figure 2: CO_2 emission reduction potential from individual measures, classified in 5 main categories of measures. Source: Bouman et al 2017.

PREDICTION OF ADDED RESISTANCE DUE TO WAVES

Contact: S.Anders Alterskjær, SINTEF Ocean & Sverre Steen, NTNU

Post doc Renato Skejic is working with development of a medium-fidelity computational method for added resistance due to waves. The method shall have better accuracy than the current methods implemented in ShipX and used in GYMIR, particularly for full ships, while it shall still only require the lines-plan type of geometry description that is currently used in ShipX. Delivery of the new method is expected in 2018.

SINTEF Ocean has extended an in-house 3D seakeeping code developed for submerged bodies to calculate mean drift forces on a floating body where the contribution from the line integral along the intersection of the body and mean free surface must be accounted for. Calculations of added resistance have been compared to verification data for both Wigley hulls and the KVLCC tanker.

The code has been found to give reliable results provided that the panels close to the free surface are not too small. The mean second-order drift forces have been found to be more sensitive than the first-order forces. It may be concluded that the code has promise for further development, and activity will be continued in 2018.

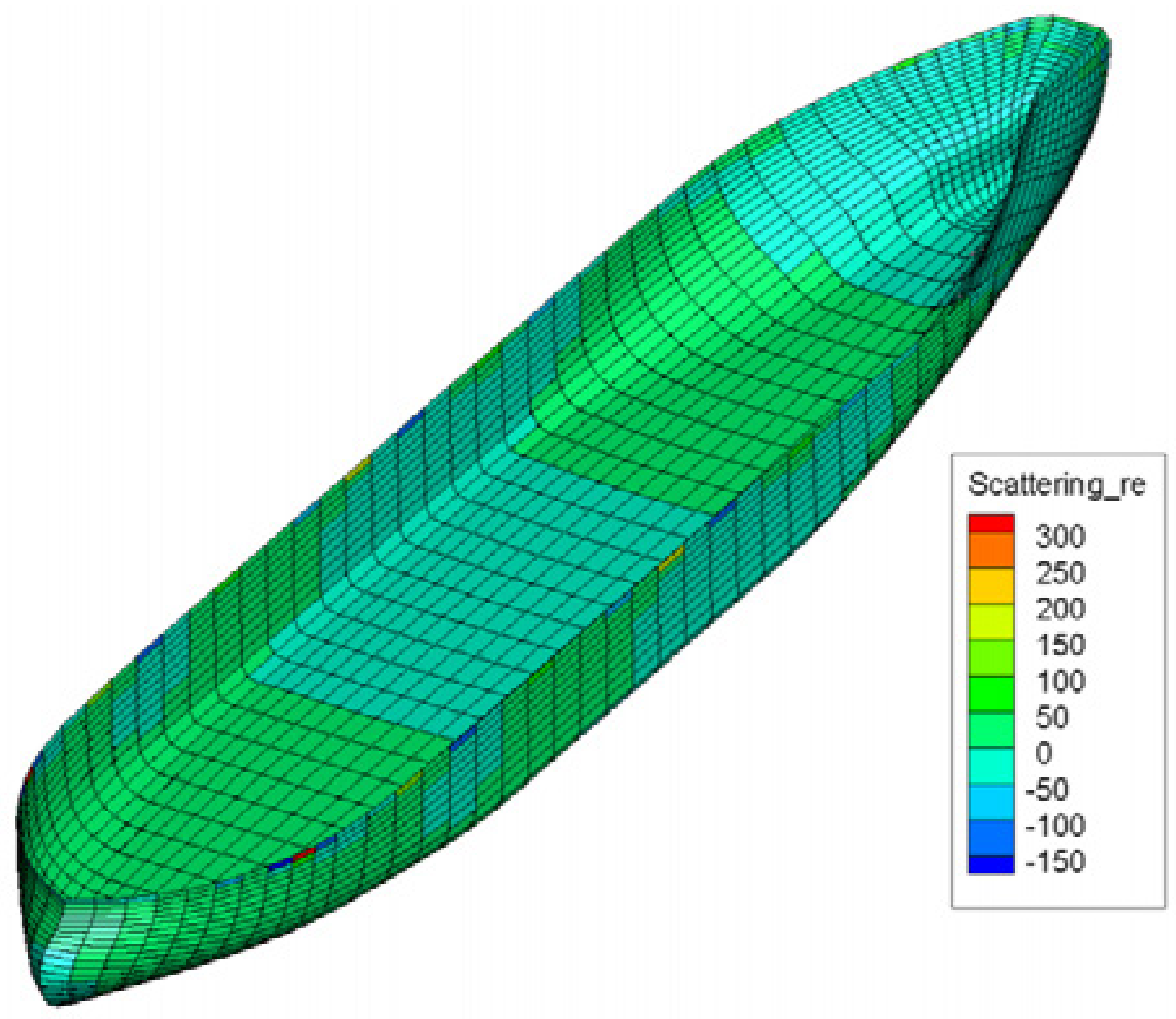


Figure 46: Real part of the scattering potential for the KVLCC2 tanker in head waves with forward speed $Fn = 0.05$ and wave period $T = 10.0$ sec.

Further, the STAWAVE method for estimation of added resistance (a "low fidelity" method based on regression formulas, for head seas) has been implemented in ShipX, currently awaiting release.

STEERING LOSSES

Contact: Sverre Anders Alterskjær, SINTEF Ocean

Speed loss in waves has been a focus of Smart Maritime research in 2017. That research aimed to gauge the speed loss arising specifically from maintaining course in waves, rather than the speed loss arising from added-resistance in waves. The work consisted of a study into past and recent innovations in the evaluation of the impact of steering on keeping speed in a seaway. Progress in a seaway can be hindered by waves, through the impact of added-resistance, changes in propulsive efficiency, and through the imposition of steering losses. These steering losses arise through the increased usage of rudders to maintain course to an accuracy suitable for the operating conditions of the vessel, and are to some extent unavoidable and to another extent minimizable. The steering characteristics of a ship, both through its fundamental design, and through the steering methodologies applied, have an extensive impact on a ship's performance in an active seaway. The energy losses which arise from the steering of a vessel in waves are consequently able to be reduced through improvements in these spheres.

In 2018, attention will be paid to systematise this research and formulate a methodology in which the steering losses of a specific vessel and propulsion combination can be evaluated in a quasistatic manner. This approach offers the potential to be integrated into GYMIR, giving a methodology by which different ship and propulsion unit combinations can be evaluated over the course of different voyage types. Furthermore, strategies will be investigated through which the efficiency of a steering method might be used to optimize given journeys, in that improved insight into speed and steering combinations could lead to an optimization process giving the ability to have an improved solution for steering and speed which give priority to either time expended or fuel consumption, or through the use of a balanced approach. The research can involve either specifying or performing suitable model tests, and the integration of this test data into ShipX and VeSim to gauge vessels' performances, and then using these metrics as input to GYMIR, through which optimizations can be sought.

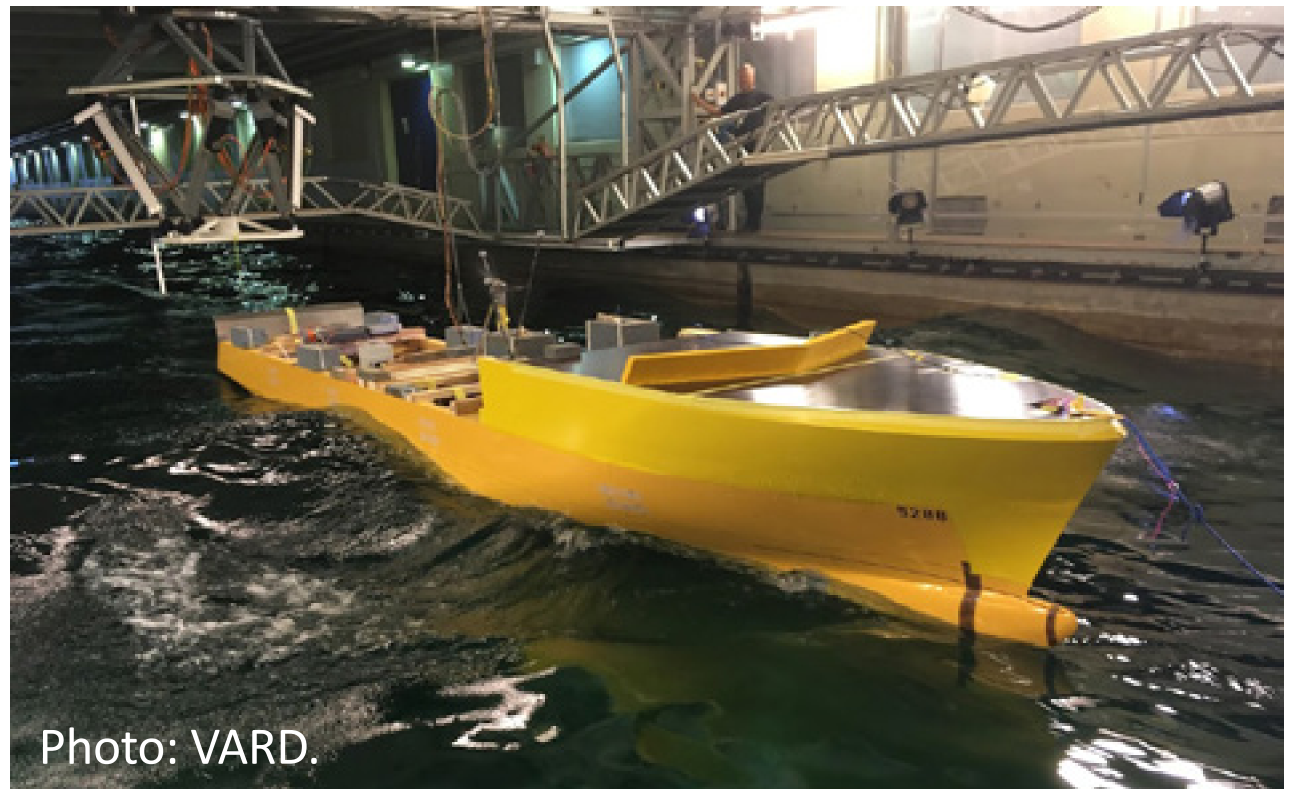


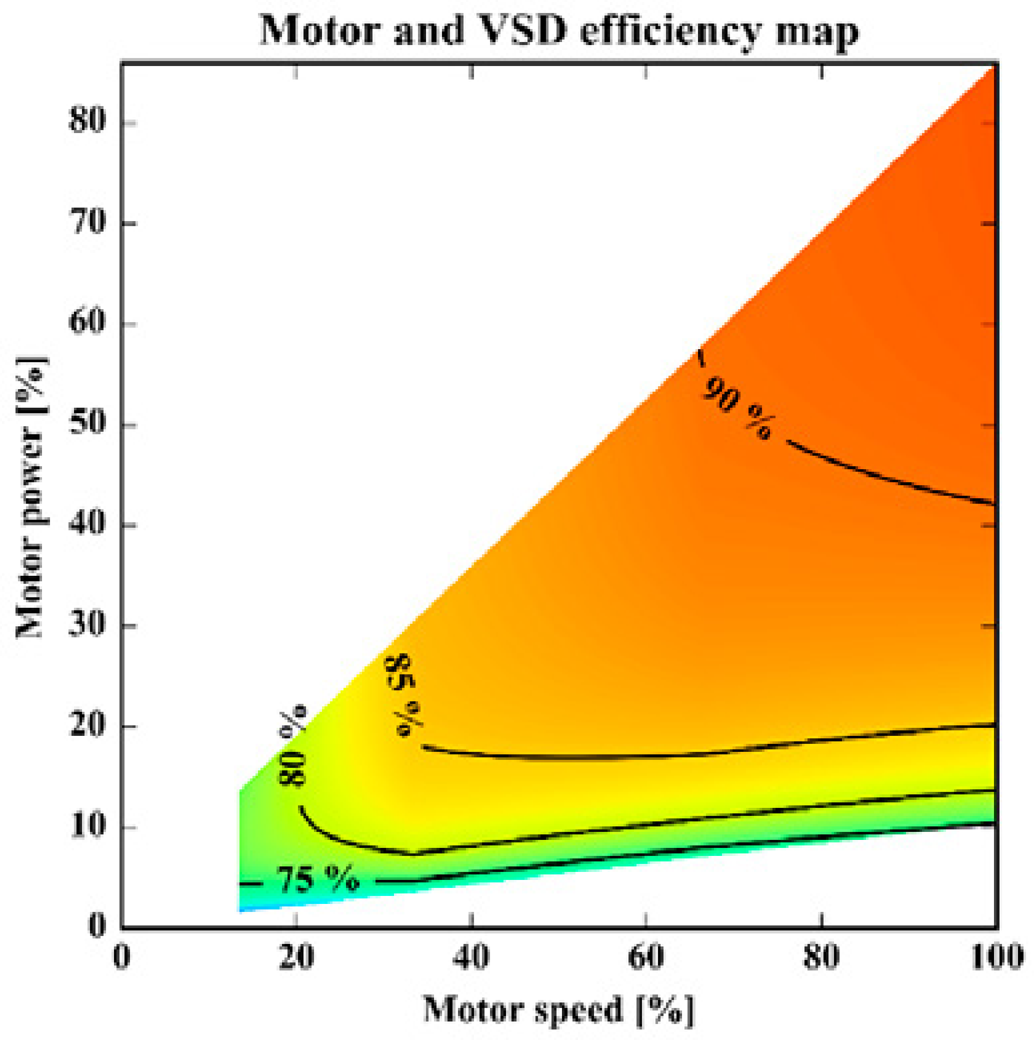
Photo: VARD.

MARINE HYBRID POWER/PROPULSION SYSTEMS

Contact: Torstein Bø & Elizabeth Lindstad, SINTEF Ocean

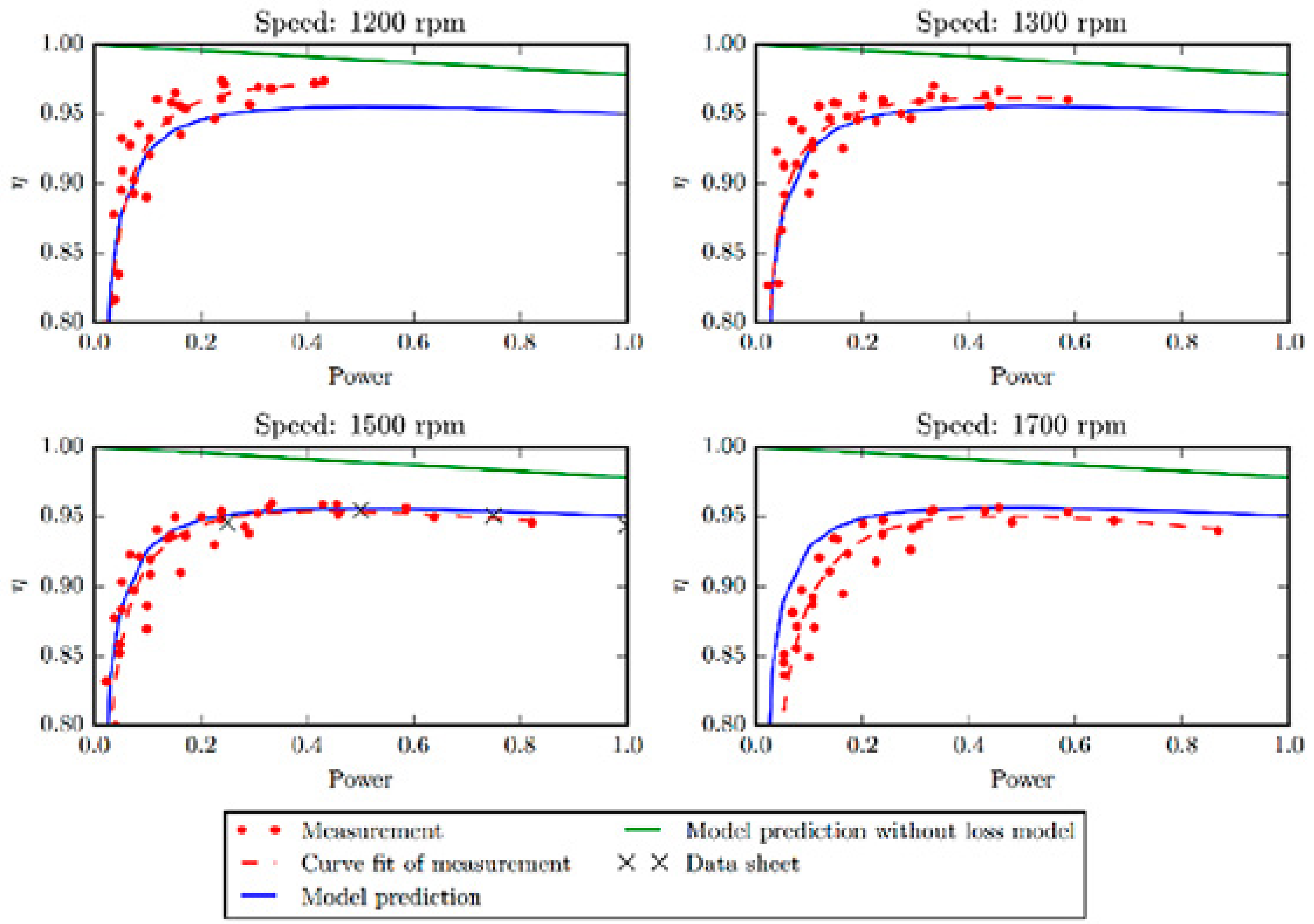
Loss investigation of marine electric propulsion systems

An investigation of losses in marine electric propulsion systems is conducted. To investigate where the losses are and to find the relevant operations.



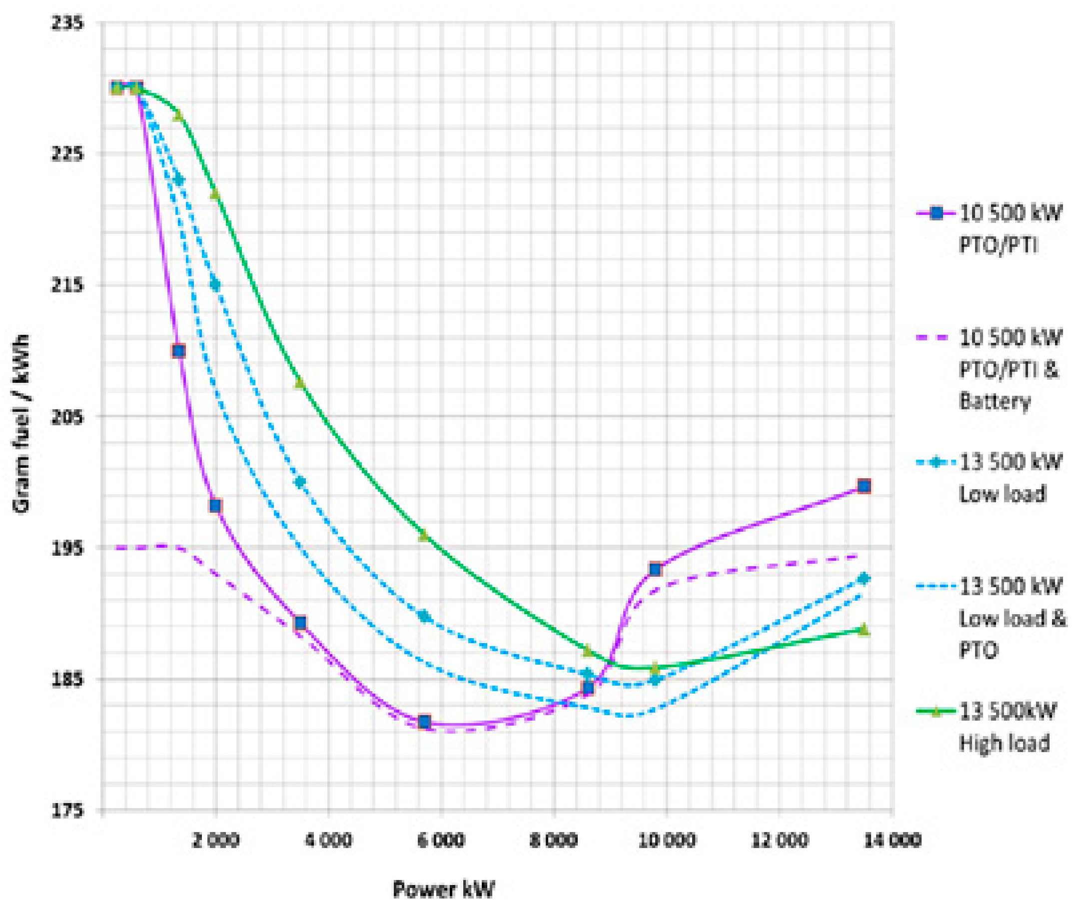
Combined loss and dynamic models of electric machines

For system designers, loss models of electric machines are needed to evaluate the performance of the drive train. These models must be in a level of details that is available for the system designer. Multiple loss models are developed for synchronous machines.



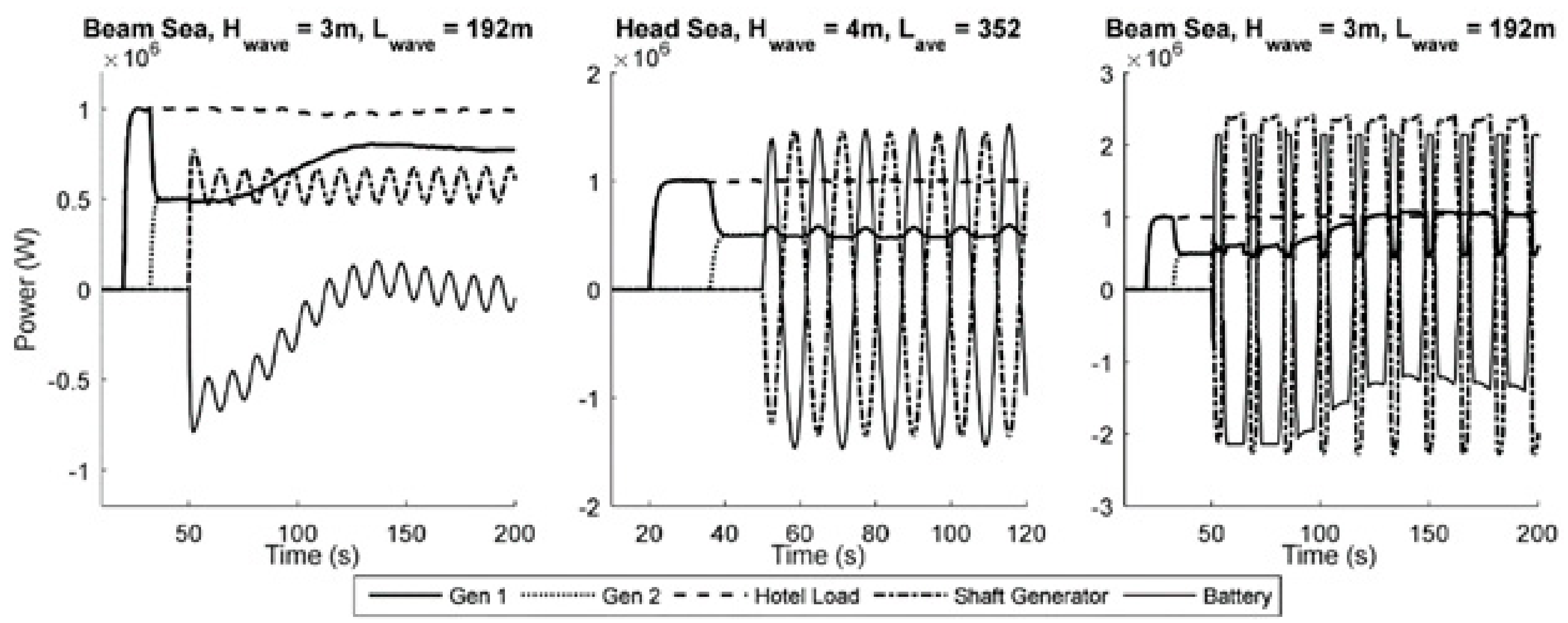
Power take in/out and batteries

For some vessels, the diesel engine is over dimensioned. Shaft generator and motors can be used to downsize the main engine while keeping the propeller shaft power capacity. The economic potential of this solution is studied in Lindstad et al. (2016).



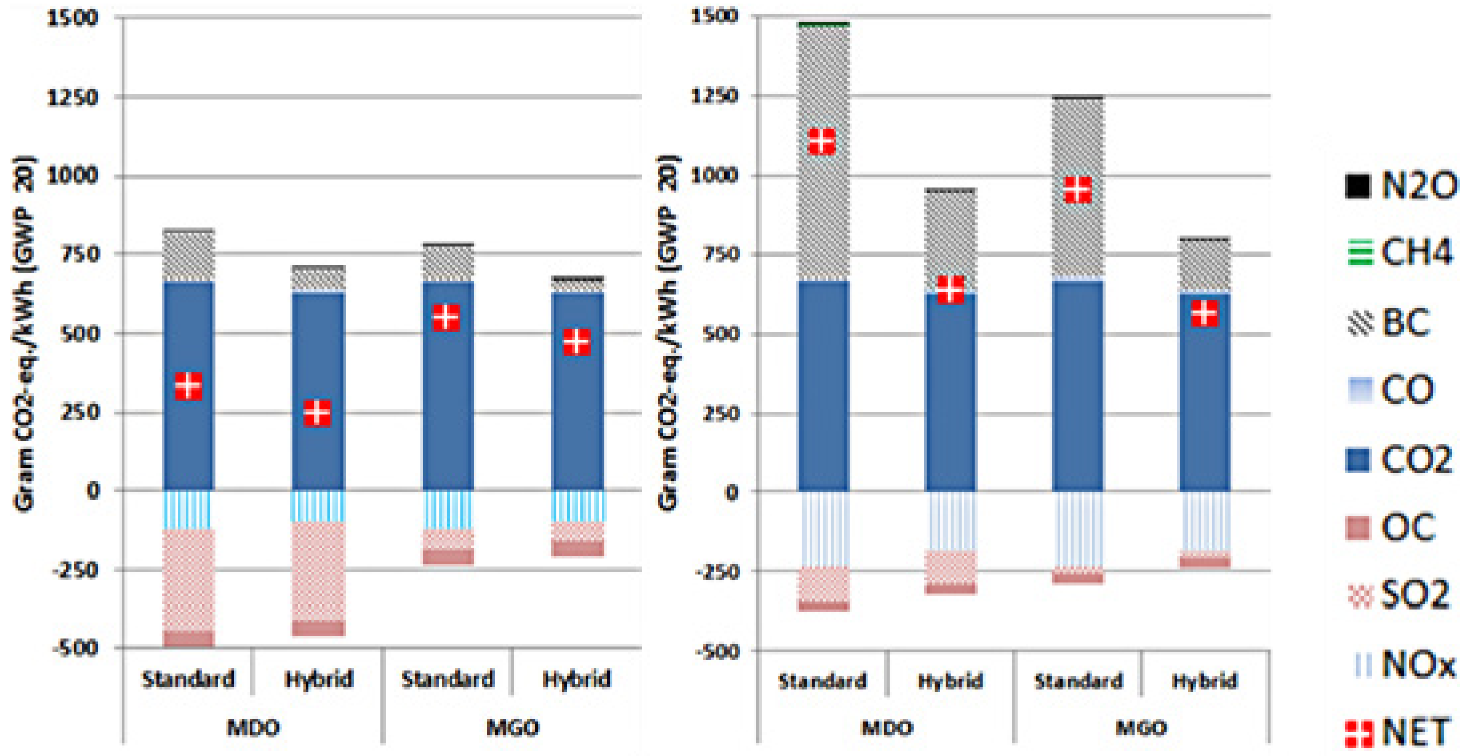
Power smoothing in waves

Power taken in/out and batteries can be used to smooth out power variations of the propeller, such that the main engine produces a constant load and batteries smooth out the variations. This method is evaluated in Yum et. al (2016).



Batteries in Offshore Support vessels

Batteries may be used in offshore support vessels to reduce environmental emissions. The greenhouse warming potential is evaluated for different locations, fuels, and configurations in Lindstad et al. (2016; 2017).



DESIGN STUDY OF THE HYBRID POWER / PROPULSION SYSTEM FOR DEEP SEA SHIPPING

Contact: Kevin Koosup Yum, SINTEF Ocean

Vessels that operates in deep sea shipping have a rather simple operation profile and often operate in a steady state conditions. Therefore, a hybrid system seems to be less effective compared to the vessels operating in offshore operation. However, the effectiveness of the hybrid solution can be obtained by optimizing the design of the overall power plant. As the main engines are designed to have enough power to overcome extreme weathers that are not very frequent, they are oversized for the most frequent operation. By providing the extra power from the hybrid power system using Power-Take-In (PTI) when required, the main engine power can be reduced, which leads to better fuel efficiency. In this regards, the true benefit of the hybrid solution has to be investigated through a design study of the hybrid power and propulsion system.

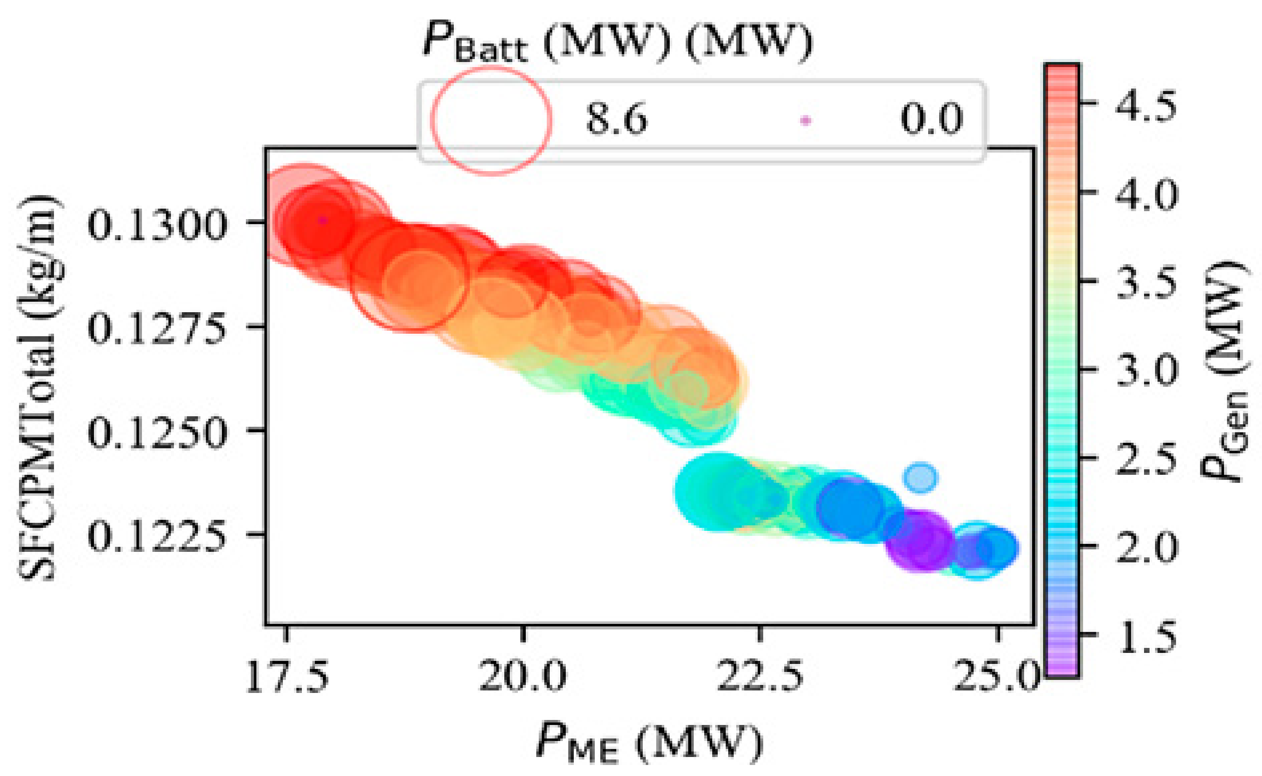
What is crucial for the design study are as follows:

1. Quality and the content of the operation profile: The operation profile should be representative for a long term operation of the vessel and be able to provide the power requirements for various operating conditions such as modes, speed and weathers.

2. Proper simulation models: The simulation models should be able to provide the accurate result as well as a good computational efficiency. That means the model should be balanced between accuracy and simplicity.

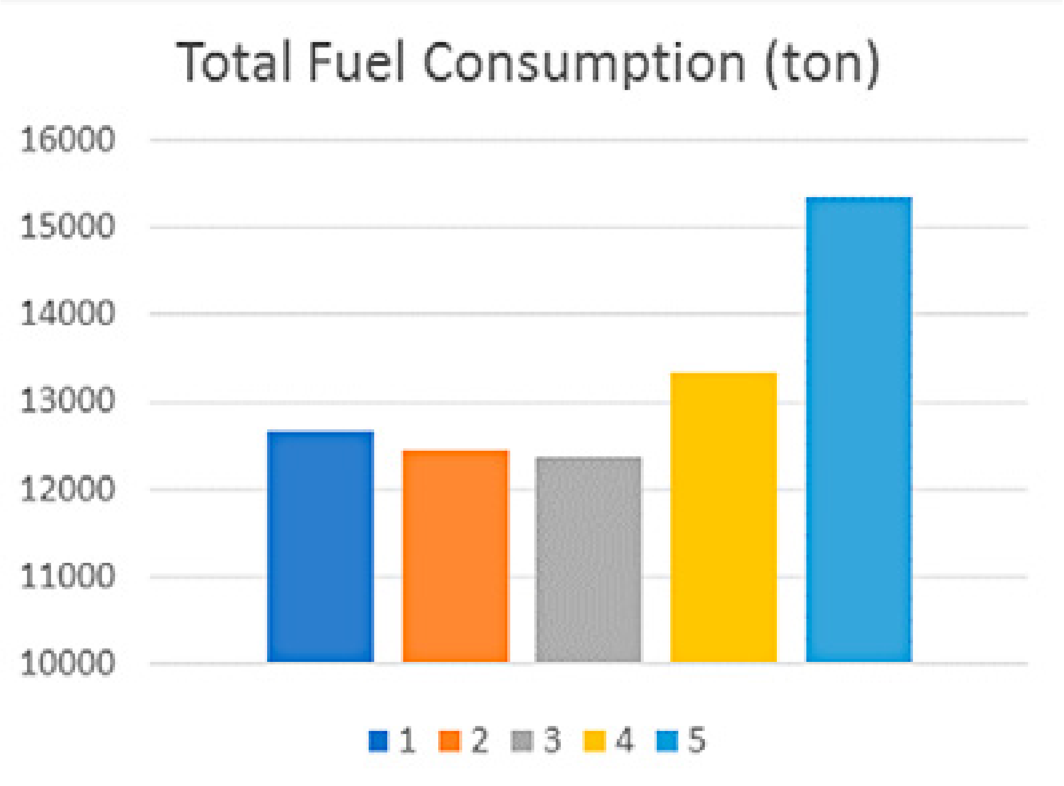
3. Design method for various simulation set up: A typical design study involves optimization of design parameters. As the simulation models are more demanding in terms of computational speed, a proper method should be employed to increase the range of design space exploration.

The first case for the design study was done for a VLCC. In this study, a detailed operational profile generated using a long-term vessel simulation and a full dynamic simulation model of a hull-propulsion-diesel engine-power system model was used. We produced a metamodel of the main performance output of interest from repeating the simulation with various design parameters, and the metamodel was used for the optimization. Figure shows the simulation result for a specific operation condition. Table shows the result of the optimization for three different scenarios.



	Base [kg/m]	Optimum [kg/m]	P_{ME} [MW]	P_{PTI} [MW]	P_{Gen} [MW]	P_{Batt} [MW]
1	0.1641	0.1627 (↓0.85 %)	24.93	1.884	1.802	1.079
2	0.1500	0.1492 (↓0.5 %)	24.41	2.375	1.641	1.266
3	0.1352	0.1339 (↓0.96 %)	23.93	3.554	1.239	2.606

The second case for the design study was to compare different powering options in terms of fuel consumption for a open-hatch bulk carrier. For this study, a long-term operational data measured onboard was obtained and used for the input of the design study. We developed a fuel-consumption calculating algorithms for a given power requirement for propulsion and auxiliary load. The algorithm can handle any type and configuration of a power system. Figure shows the comparison of the different power system options for the given operating data.



Main Engine	Aux. Engine [kW]	PTI/PTO [kW]	[kW]
1.2 Stroke	1 x 10480	3 x 960	0
2. 2 Stroke + Shaft generator	1 x 10480	2 x 960	960
3. 2 Stroke + PTI/PTO	1 x 8000	2 x 1050	2000
4. 4 Stroke + PTI/PTO	2 x 4800	1 x 4720	1500
5. Diesel Electric	3 x 4720	-	0

METHANE SLIP FROM GAS FUELLED ENGINES

Contact: Dag Stenersen, SINTEF Ocean

A project co-funded by the Norwegian NOx-Fund, the Norwegian Environment Agency and SFI Smart Maritime with objectives to strengthen the knowledge about air emissions and measures to reduce emissions from marine gas engines. The main purpose was to do emission measurement on several ships and engines types to obtain state of the art data for new gas engines in operation. Through a measurement campaign, emissions from gas fuelled engines has been verified. Specific focus was on methane slip from these engines, but emission components as NOx, THC (CH4), CO and CO_2 were measured.

In the project several ship owners placed their ships at disposal for on-board measurements to obtain updated emissions factors from ships in operation. Measurements were done on several ship types as ferries, product tankers and bulk ships. Laboratory measurements was also done in the laboratories of one engine manufacturer.

Gas fuelled bulk ship operated by KGJS. Photo courtesy: Ferus Smit.

Main findings from the project was that methane slip from gas fuelled engines for marine application are significantly reduced during the last few years. Previous work by SINTEF Ocean (former MARINTEK) showed significant higher methane emissions than what is observed today. Especially low load operation has improved.

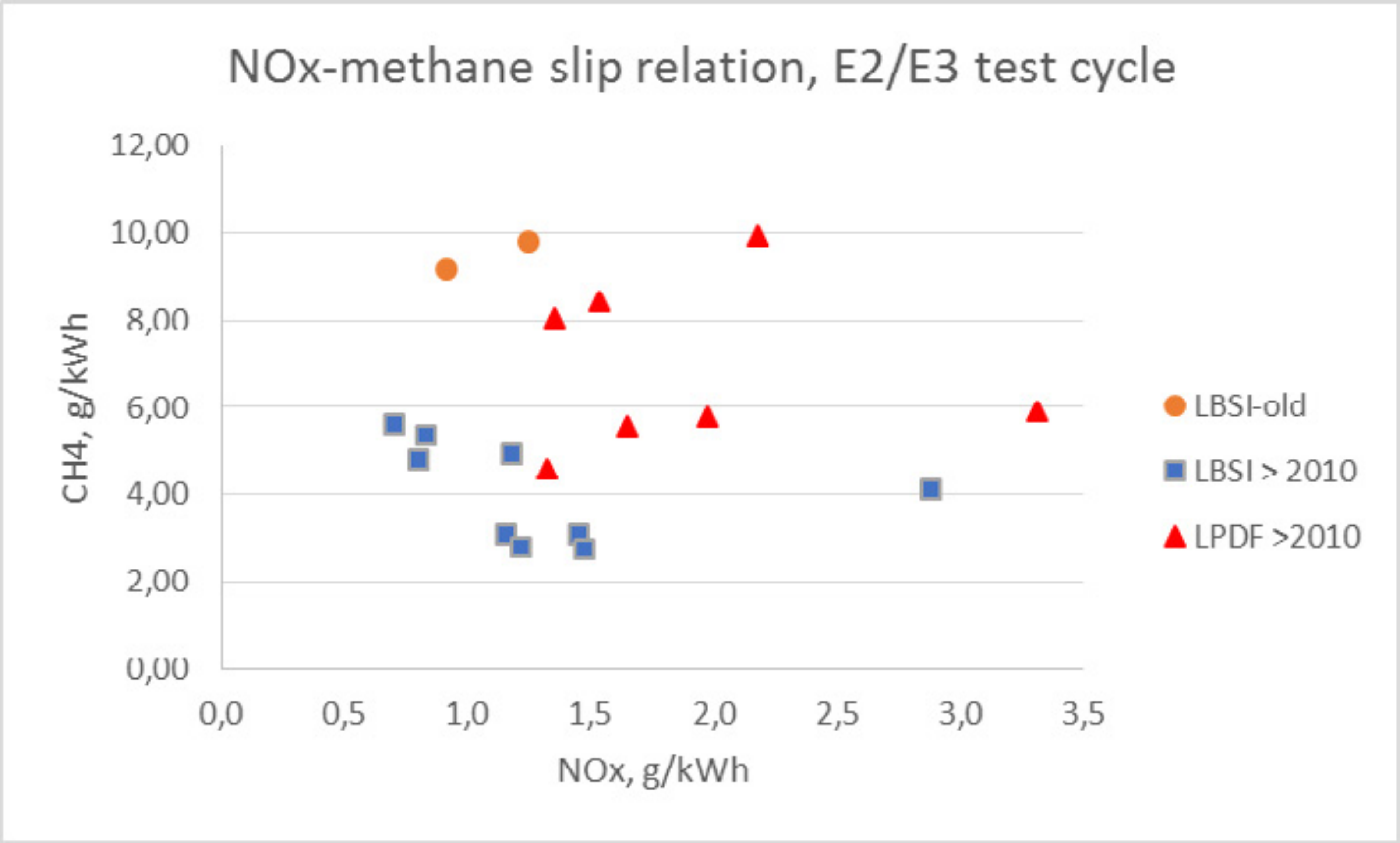


Figure 1. Specific methane slip versus NOx emissions for gas fuelled engines, E2/E3 test cycle, based on on-board measurement on ships and manufacturer test bed data, total of 18 engines test protocols.

However, on-board measurement show that specific methane emissions are relative high on these operation points, and this may be of concern for ships where low load operation is required. In general, it can also be concluded that Lean burn SI engines has a lower NOx/methane-slip relation than 4-stroke Dual Fuel engines as indicated below.

Based on project results new emission factors was recommended for use in emission inventories and emission calculations from gas fuelled ships. Project results are available in a public report.

Ref.:
Stenersen D., Thonstad O.: “GHG and NOx emissions from gas fuelled engines” sintef Ocean report OC2017 F108. 2017-06-13.

ABATEMENT TECHNOLOGIES

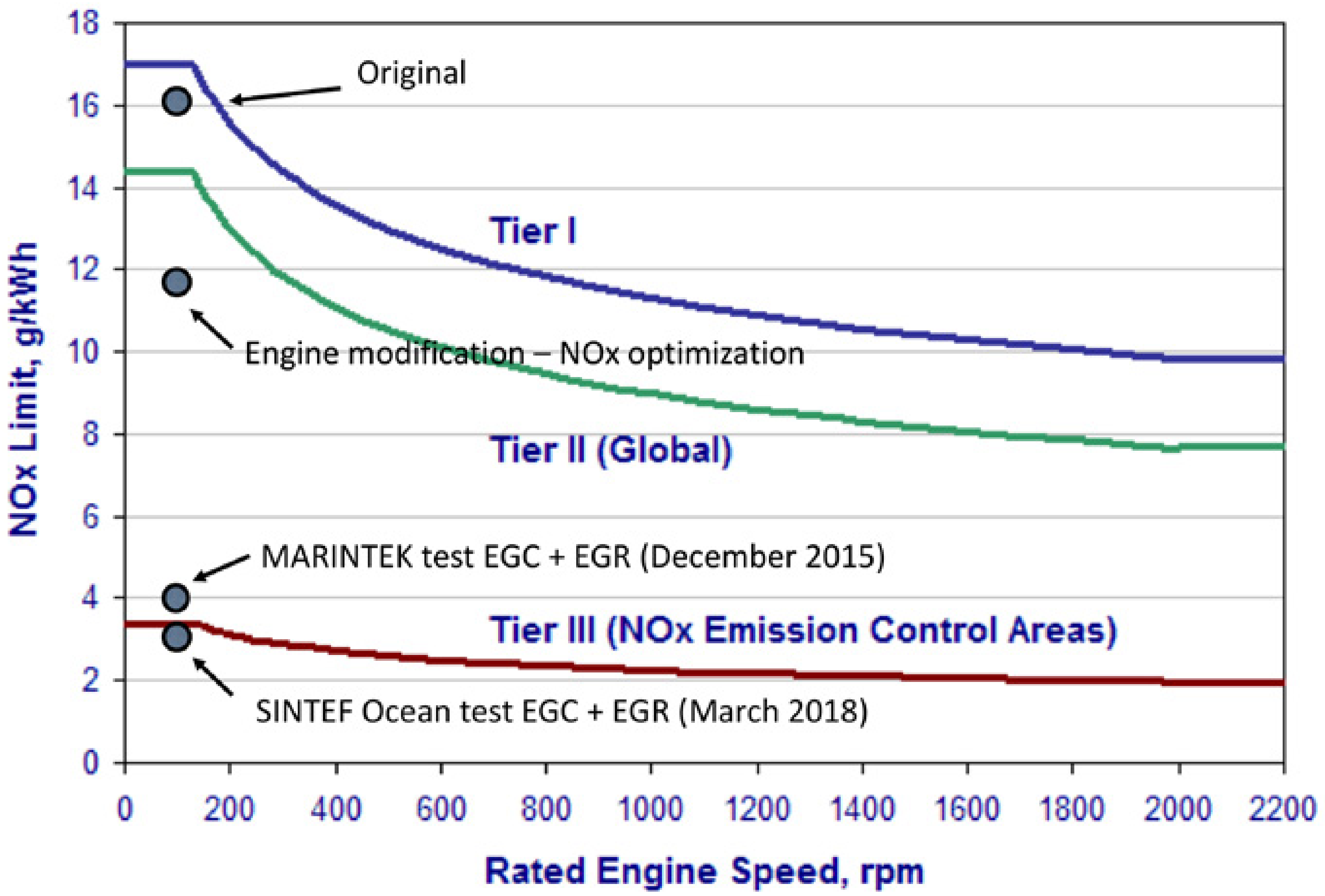
Contact: Ingebrigt V., Ole Tonstad, Per Magne Einang, SINTEF Ocean

The ship is in addition using Exhaust Gas Recirculation (EGR) to control NOx emission. New measurements have been performed showing NOx emissions meeting the IMO Tier III target with about 30 % EGR. Cylinder pressure was recorded and used to calculate RoHR (Rate of Heat Release) and thermal efficiency. These calculations indicate 2,0 – 2,5 % increase of fuel consumption of main engine.

Clipper Harald. Photo: Solvang.

A test on improved EGR quality showed a reduced need for turbine and heat-exchanger washing.

New measurements and analysis of washing-water quality were also performed showing very low levels of harmful components, due to the wash water cleaning system.



INNOVATIVE SHIP CONCEPTS FOR DEEP-SEA OPERATORS DEVELOPED WITH GYMIR TOOL

Contact: Trond Johnsen & S. Anders Alterskjær, SINTEF Ocean

The GYMIR tool for simulation-based concept design has been further developed in 2017, with focus on enhanced functionality for studying deep-sea shipping operations. This has been demonstrated in two different case studies:

Open hatch bulk carrier concept for Grieg Star Shipping

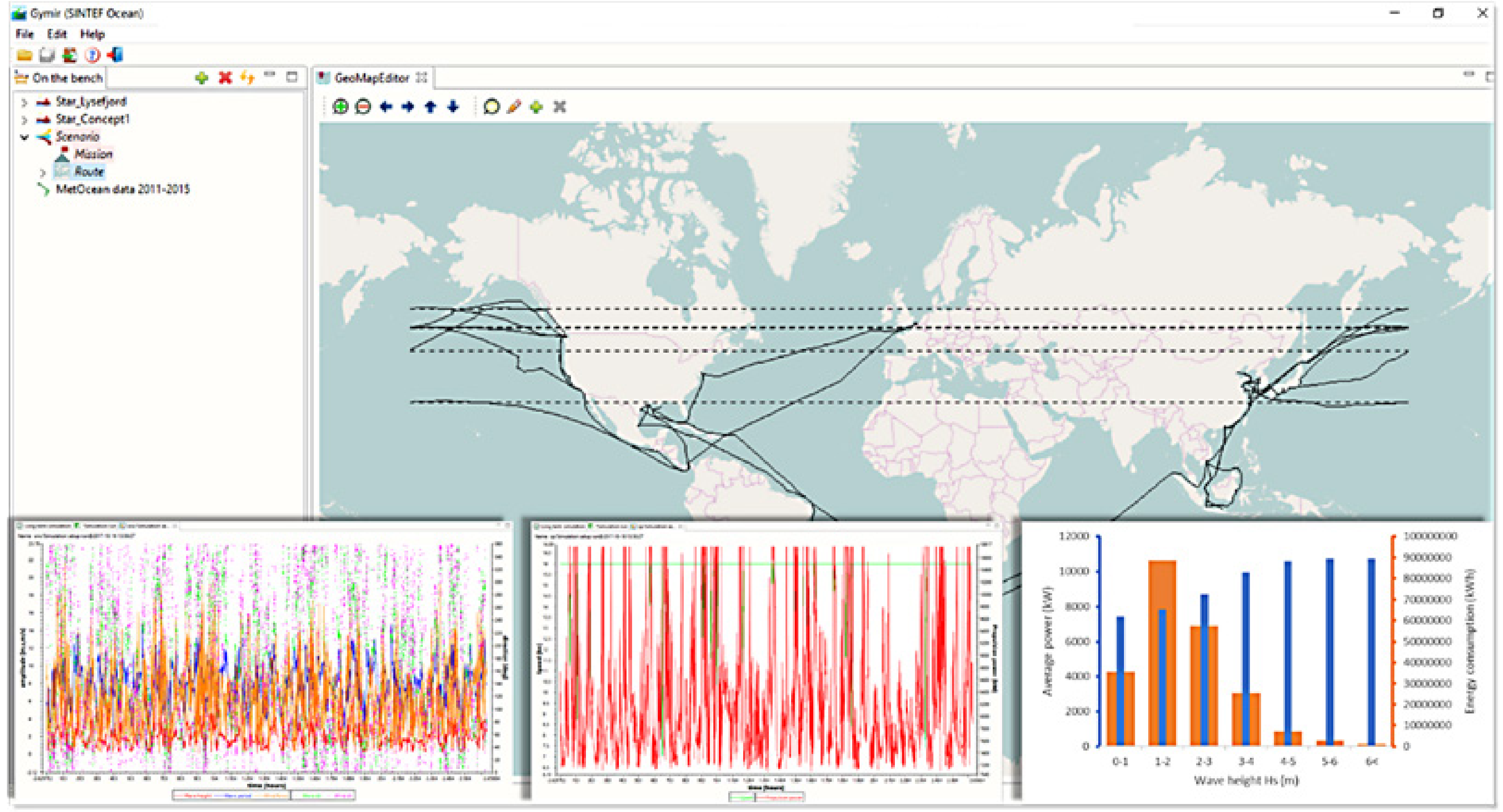
Photo: Grieg Star.

Ro-Ro ship concept for Wallenius Wilhelmsen Logistics

Photo: Wallenius Wilhelmsen Logistics.

In both cases, the existing requirements and boundaries, both technical and commercial, for ship designs have been challenged.

Through several iterations of modelling and analyses with the GYMIR tool, one has arrived at new concept designs with significant improvement in energy efficiency and reduced environmental footprint.



Snapshot of GYMIR workbench.

VALIDATION STUDY OF THE GYMIR VIRTUAL TESTING WORKBENCH

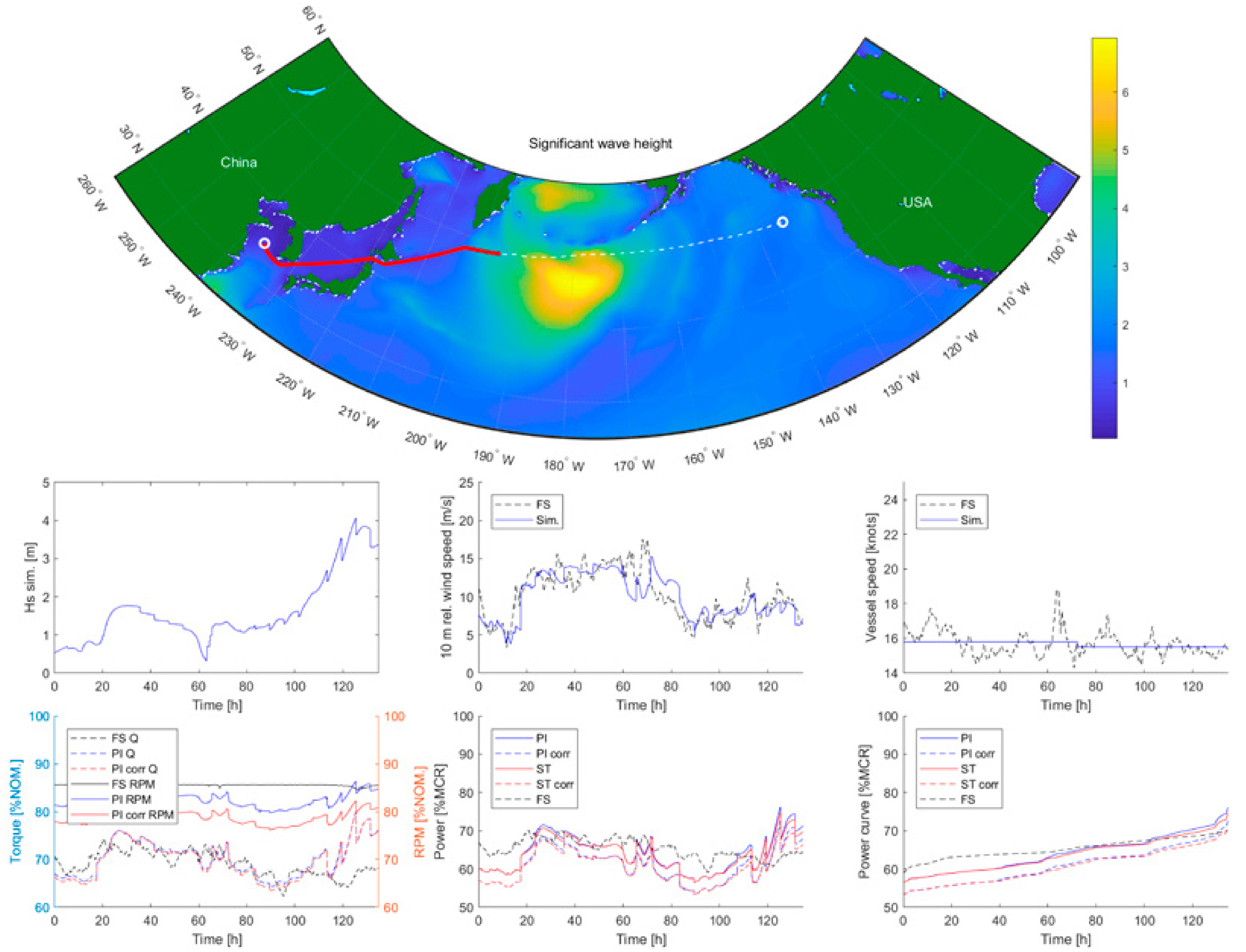
Contact: Endre Sandvik, NTNU

GYMIR is developed as a tool for virtual testing of ship design solutions, providing insight that improve early stage design decisions. The validity of the GYMIR simulation results was tested in a case study using full-scale data from a performance measurement system onboard a real vessel. The chosen case vessel is a general cargo carrier.

The study focused on the required propulsion power and fuel consumption estimates. Calm water resistance curve and propulsion characteristics from experimental tests was applied. Wave added resistance was estimated using the strip theory (ST) and pressure integration (PI) approach. Full-scale data (FS) was used as reference for validation.

GYMIR was set to replicate a case vessel route from Qingdao (China) to Seattle (USA), covering a distance of 4514 nautical miles over 12 days. Historical weather data from the ECMWF database was ap-plied to replicate the operating conditions.

The study is documented in a conference paper and will be presented at IMDC 2018 in Helsinki.



MARITIME TRANSPORT ENVIRONMENTAL ASSESSMENT MODEL (MariTEAM)

Contact: Anna Ringvold & Anders Strømman, NTNU

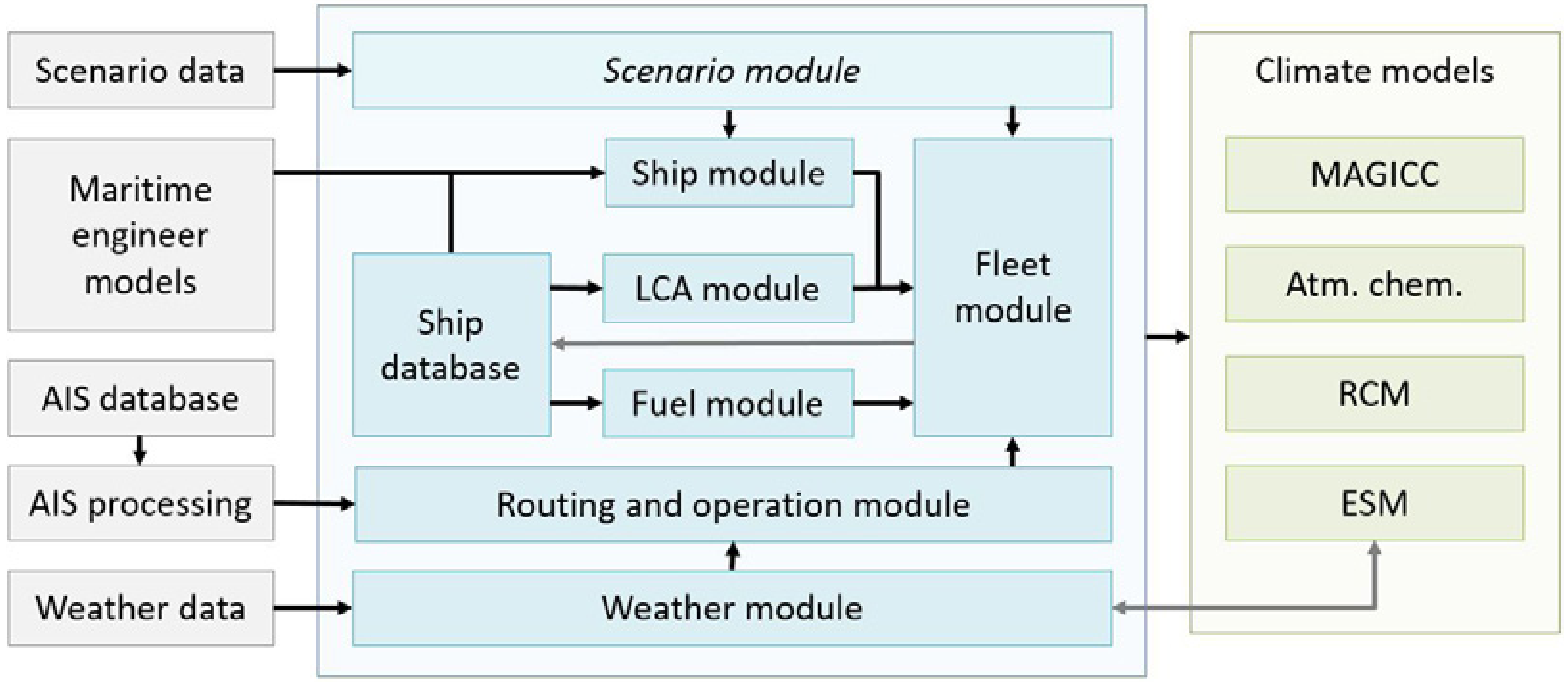
A second iteration of MariTEAM (Maritime Transport Environmental Assessment Model) was commenced in 2017. Satellite data from the Norwegian Coastal Administration expanded the ambition of the project as we are now able to perform spatial-temporal analysis of ship emissions. Altering course to more comprehensive analyses rather than case studies necessitates a greater degree of quality control of databases, which has been carried out in 2017.

The MariTEAM model has become more modular and currently consists of four modules: Ships, Tracks, Engines and Weather. The modules can be combined in different sets, and there are at the moment two operational implementations of the model: Basic and Weather. The output from the model is formatted so it can be used in climate models. The other work packages in Smart Maritime have been invaluable when developing these modules, especially WP3 on the Engine module and WP2 for the Weather module. Close cooperation with well-developed academic institutions leads us to believe that MariTEAM is more technologically robust on the marine technology than other similar tools.

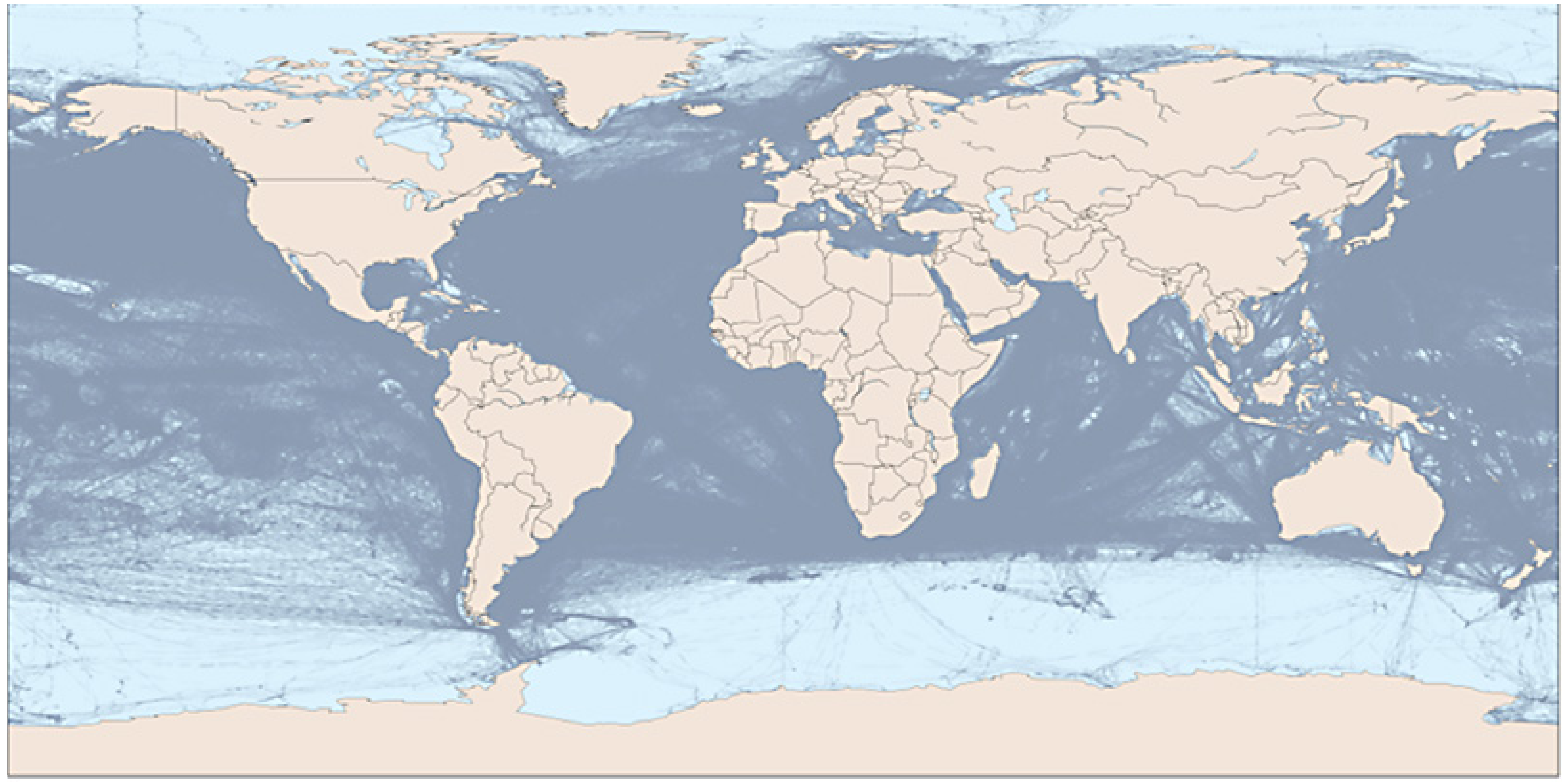
We envision MariTEAM will attain new capabilities over time, with the LCA and Scenario classes being the next on the list. Prof. Strømman presented the model and its future development at the 8th International Conference on Life Cycle Management in September, and reaped praise and positive feedback for the initiative.

Over the fall semester 2017 MSc student Mario Salgado assembled a life cycle inventory of a sulphur scrubber for 4500 TEU container ship and conducted a life cycle assessment on its application. He will in 2018 deliver a master thesis on the topic of reconciling big data on trade statistics and ship traffic.

Structure and integration of current and future modules in the MariTEAM.



Global shipping activity at sea in 2015 as recorded by Norwegian Coastal Administration's satellites.



COOPERATION

SKS Satilla. Photo: Capt R. Revnyuk, Kristian Gerhard Jebsen Skipsrederi.

INTERNATIONAL COOPERATION

R&D cooperation

The EU H2020 project HOLISHIP is ongoing, with the participation of Smart Maritime partners SINTEF OCEAN, DNV GL and Rolls Royce (UK). The project is dedicated to *HOLIstic optimisation of SHIP design and operation for life cycle.* One of its activities is directed to the development and testing of a Virtual Vessel Framework for optimization of design and concept validation.

Scientific and academic cooperation

The SFI has had two meetings with its Scientific Advisory Committee, which resulted in valuable scientific discussion and advice on further work. The Committee members are: Professor Osman Turan from Strathclyde University, Professor Harilaos Psaraftis from Technical University of Denmark, Professor Karin Andersson and Rickard Benzow from Chalmers University of Technology, and Professor Friedrich Wirz from TU Hamburg.

Cooperation NTNU / DTU (Denmark) on common PhD program

Two PhD students are funded by the Rectors of NTNU and DTU as part of an initiative to promote cooperation between the two institutions. One PhD, employed at DTU, is focusing on hydrodynamics of propulsion in waves (WP2), while the other is employed at NTNU focusing on methane slip in LNG engines related to dynamic loads (WP3). The two PhDs will work in cooperation. The PhD projects will cooperate with SFI Smart Maritime.

Cooperation with Chalmers University of Technology, Sweden

Cooperation with WP2 (and joint work with JOTUN) within fouling and anti-fouling for reduction of friction.

NATIONAL COOPERATION

Smart Maritime cooperates with SFF AMOS, SFI EXPOSED, SFI MOVE and SFI SAMCoTthrough *Ocean School of Innovation*. The main goal is to increase innovation and value creation of the research centres by strengthening the awareness and competence on innovation and entreneurship among PhD students.

Henning Borgen from SINTEF Ålesund has been appointed as coordinator across three SFIs: Smart Maritime, MOVE and EXPOSED. The coordination focuses on tool and model development.

Henning Borgen
SINTEF Ålesund

SFI Smart Maritime has ongoing cooperation with Patentstyret on a Patent Landscape Analysis. The analysis consists of a preliminary examination of the scope for action on the main technologies under consideration in Smart Maritime (geographical patenting activities, largest players etc.).

DIALOG WITH THE NORWEGIAN RESEARCH COUNCIL

SFI Smart Maritime partitipated at the SFI-forum 2017, hosted by the Norwegian Research Council in April 2017, gathering 90 participants. The SFI Forum is a meeting place between SFIs and the Norwegian Research Council, with the purpose to exchange experience from SFI activities, challenges, success stories. In 2017, topic discussed included communication, commercialisation of results, and the process of evaluation of the SFI-support scheme.

Photo: Grieg Star.

ASSOCIATED PROJECTS

Project name	Description	Synergi with Smart Maritime	Schedule & Funding
HOLISHIP HOLIstic optimisation of SHIP design and operation for life cycle	The vastly increasing complexity of European built ships and maritime structures as well as the growing number of rules and regulations call for novel concepts of product design and testing. The project will develop a multi-objective, - disciplinary and multifidelity ship design and optimisation framework. www.holiship.eu	WP4, SP3 Virtual prototyping	2016-2020 EU H2020 MG-4.3-2015
Hybrid testing Real-Time Hybrid Model Testing for Extreme Marine Environments	The project focuses on resolving the challenges in the model test in the laboratory with regard to scaling, physical availability and expenses by replacing a substructure of the model by a numerical simulation running in parallel. Among other work packages, the work package 4 concentrates on the testing of a marine hybrid power plant with the simulation of the vessel motion and propulsion.	WP3 Power systems WP4 Ship system integration	2016-2020 NRC MAROFF

Methane emissions from gas engines	Methane emissions from gas engines: mapping, verification, technologies for reduction. This projet aims at strenghening knowledge om harmfull air emissions and measures for emissions reduction.	WP3, SP1 Fuels and abatement technologies	2016–2017 Miljødirektoratet NOx-fondet
ViProma Virtual Prototyping of Maritime Systems and Operations	Objective: to design an open framework for virtual proto-typing and simulation of maritime systems and operations. https://viproma.no/doku.php?id=viproma:about	WP4, SP3 Virtual prototyping	2013–2016 NRC MAROFF
Vista Virtual sea trial by simulating complex marine operations	The purpose of VISTA is to develop an innovative, integrated software-package for design of the ship of the future. This will give te possibility to simulate, analyse and compare effectively the performance of a complete system.	WP4, SP3 Virtual proto-typing	2014–2016 NRC MAROFF

RECRUITEMENT

Ponant Icebreaker. Photo: Vard and Sterling Design.

Smart Maritime is a scientific and industrial network of over 100 people. The research team consists of over 30 research scientists from two institutions NTNU and SINTEF Ocean, including 3 Postdocs and 5 PhD students.

PHD AND POSTDOC RESEARCH PROJECTS

Smart Maritime has reached almost 50 % of its recruitment target of 9 PhD and 8 Postdocs by 2023. In addition, 8 PhDs and 1 Post-doc with funding from other sources are currently connected to Smart Maritime activity. PhDs and Postdoc are involved mostly in activities from WP2, 3 and 4.

The NTNU team has also supervised 9 MSc theses during 2017.

Training of PhD candidates and MSc students is a prioritized activity. The methodological platform for innovations and verification of ship designs envisioned in Smart Maritime will contribute to educating a new line of engineers (MSc and PhD) with a multi-disciplinary focus.

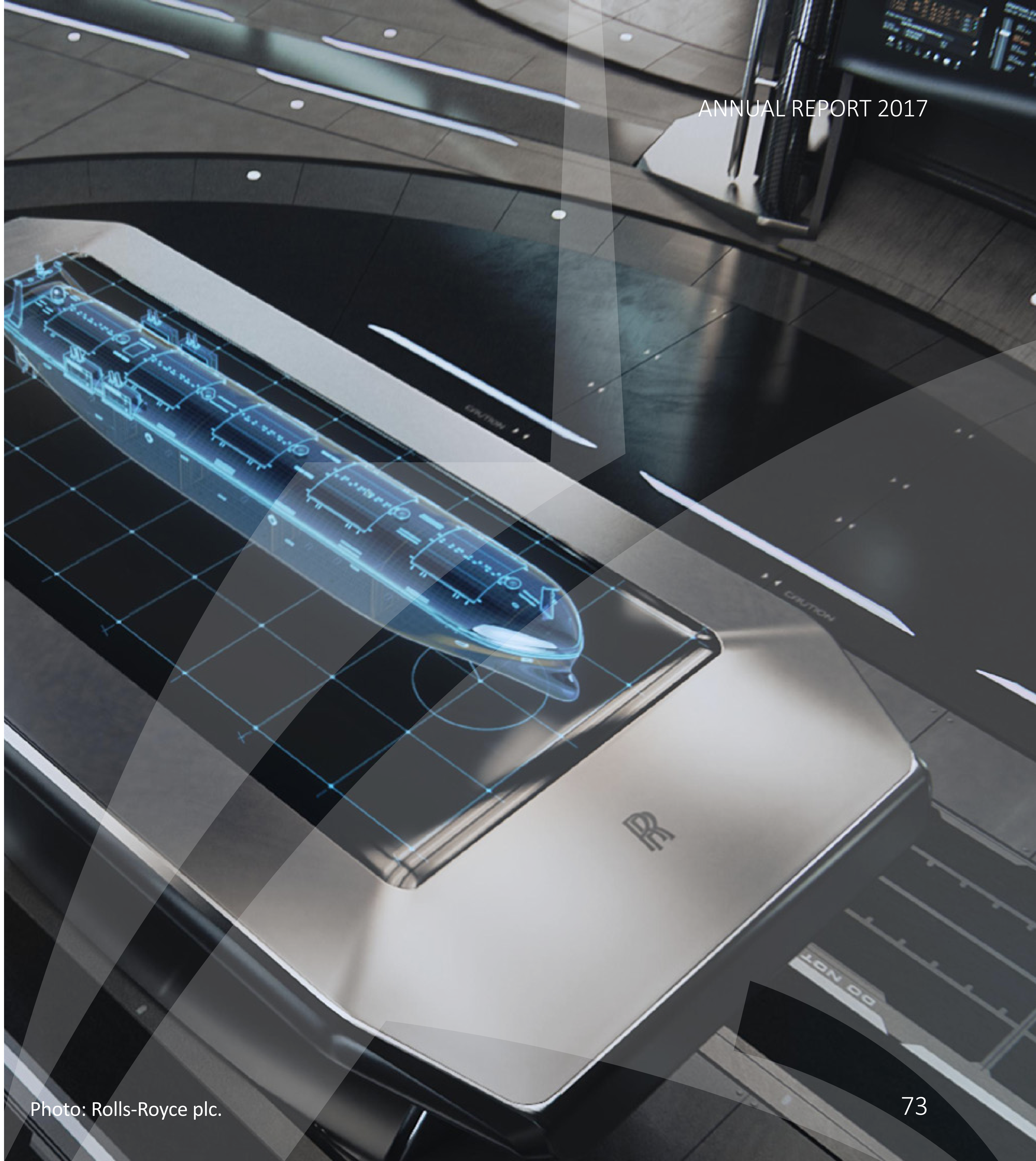


Photo: Rolls-Royce plc.

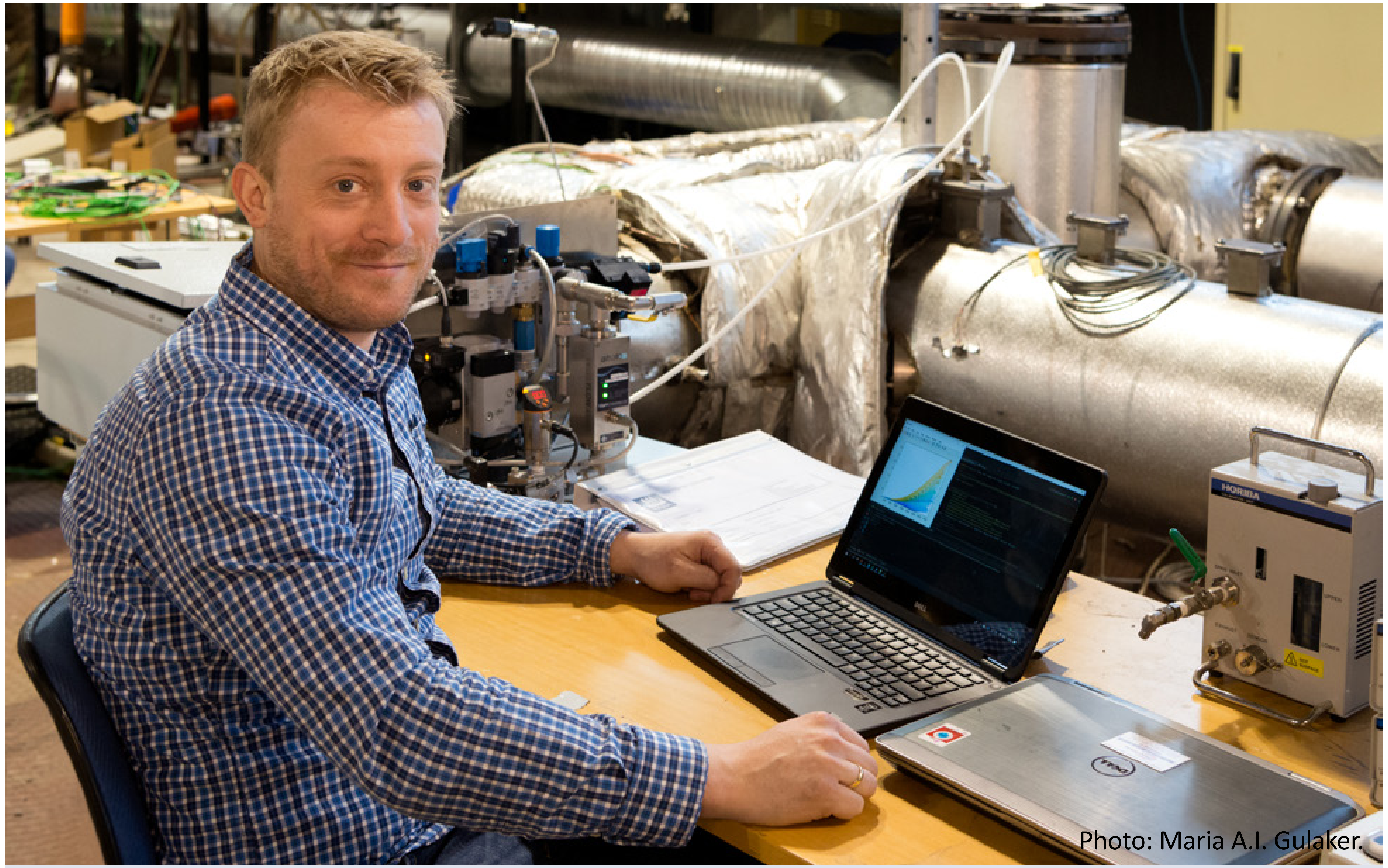


Photo: Maria A.I. Gulaker.

Jørgen Nielsen

PhD Student WP3/WP4 (2015–2018)

Simulation of complex high efficiency maritime power systems

Research goal and strategy

The main research goal is to improve energy utilization in marine power systems by looking at possibilities emerging with hybrid power technology and energy harvesting. The main area of research is system dynamics which plays an important role in the control and optimization of complex systems. The approach includes creating dynamic models of required equipment in the power system and simulation of complex power system solutions. If possible, model validation with real world systems will be a priority. The outcome of the work is aimed at providing concept evaluation of new marine power system design with improved energy efficiency and increased system flexibility both for the deep sea and offshore segments.

Foreseen innovation

System concepts for improved energy efficiency and reduced emissions.

Main achievements 2017

Submission of two papers

- A system approach to modelling heat exchanger and heat exchanger network dynamics using bond graphs.

- A system approach to Selective Catalyst Reduction DeNOx monolithic reactor modelling using bond graphs.

John Martin Kleven Godø
PhD student WP2
(2015–2021)

Hydrodynamics of hydrofoil vessels

Photo: Maria A.I. Gulaker.

From PhD student to entrepreneur
2017 has been an exciting year for me. During this period my daily job has changed from PhD student into an entrepreneurial role in an NTNU Technology Transfer commercialization project entitled Flying Foil. I am now on a 100 % leave from my PhD studies to focus on the product development and commercialization part of the *Flying Foil project.*

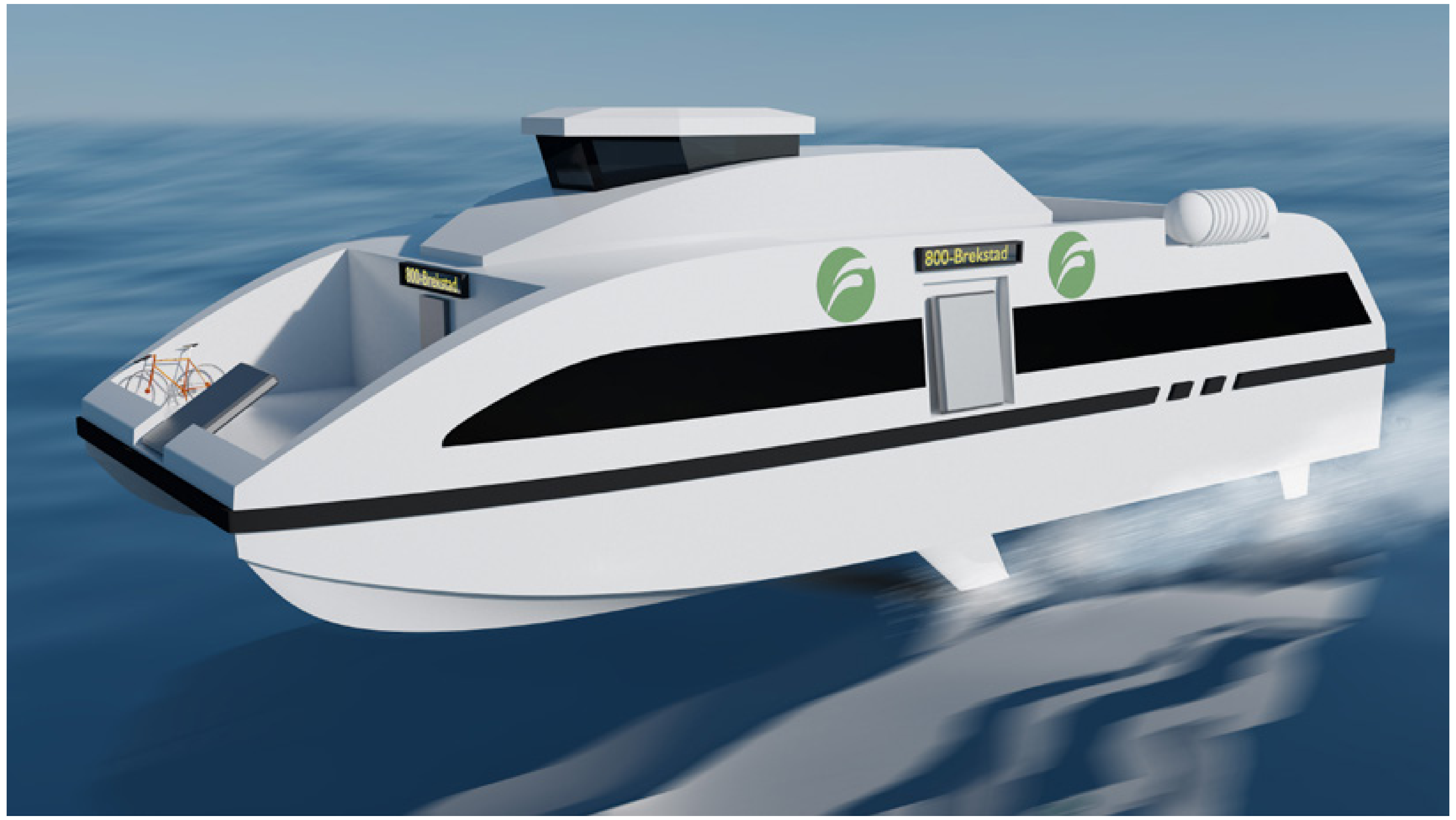
As a result of the emerging of the commercialization project, my study topic has also been changed slightly. Where it originally aimed at investigating the hydrodynamics of hydrofoil vessels with biomimetic propulsion systems, we have now changed focus into more general investigation of the hydrodynamics of hydrofoil vessels.

During the PhD-study part of 2017 I have worked on the development of an unsteady lifting line code for simulation of hydrofoil flight and seakeeping. In short this is a type of code which can give very fast simulations of unsteady hydrofoil lift and drag, for instance in situations of fluctuating inflow due to waves or oscillations due to vessel motions. An initial validation study towards 2D analytical theory has indicated relatively accurate results. The next step in this context is to run CFD simulations for validation in 3D conditions. Eventually the code will be embedded into a motion and control system simulator framework. The goal is to be able to experiment with different foil system layouts and control system settings and get quantitative data on how this affects seakeeping and added resistance when running in waves.

Flying Foil

Flying Foil is a start-up project aiming to develop and commercialize a new generation of hydrofoil vessels for use in passenger transport. The principle of lifting a vessel on hydrofoil has great potential, and current calculations indicate that it might be possible to reduce the energy requirement of a 35 knot fast ferry by more than 30 % as compared to the best conventional vessels of today. This translates to more lightweight machinery and energy storage and thereby a positive design loop yielding further reductions of power requirement.

During the year we have established a collaboration with Norway's leading fast ferry shipyard, Brødrene Aa, with the aim of building a fully electric 7 meter prototype vessel of our current hydrofoil design. This will be a combined development/learning and demonstration project, in which we hope to get a confirmation of simulated energy requirement and to learn more about construction methods and flight control systems. Norges Forskningsråd is supporting this prototype project through the «Forskningsbasert Nyskaping (FORNY)»-grant, which will keep the commercialization project running for approximately 1.5–2 years. Several of the Norwegian county administrations, which purchase public ocean transport, have shown interest in our project.



Copiright: Flying Foil/Jarle Kramer.

Endre Sandvik

PhD student WP4
(2016–2019)

Simulation Based Design of Ships With Regards to System Performance

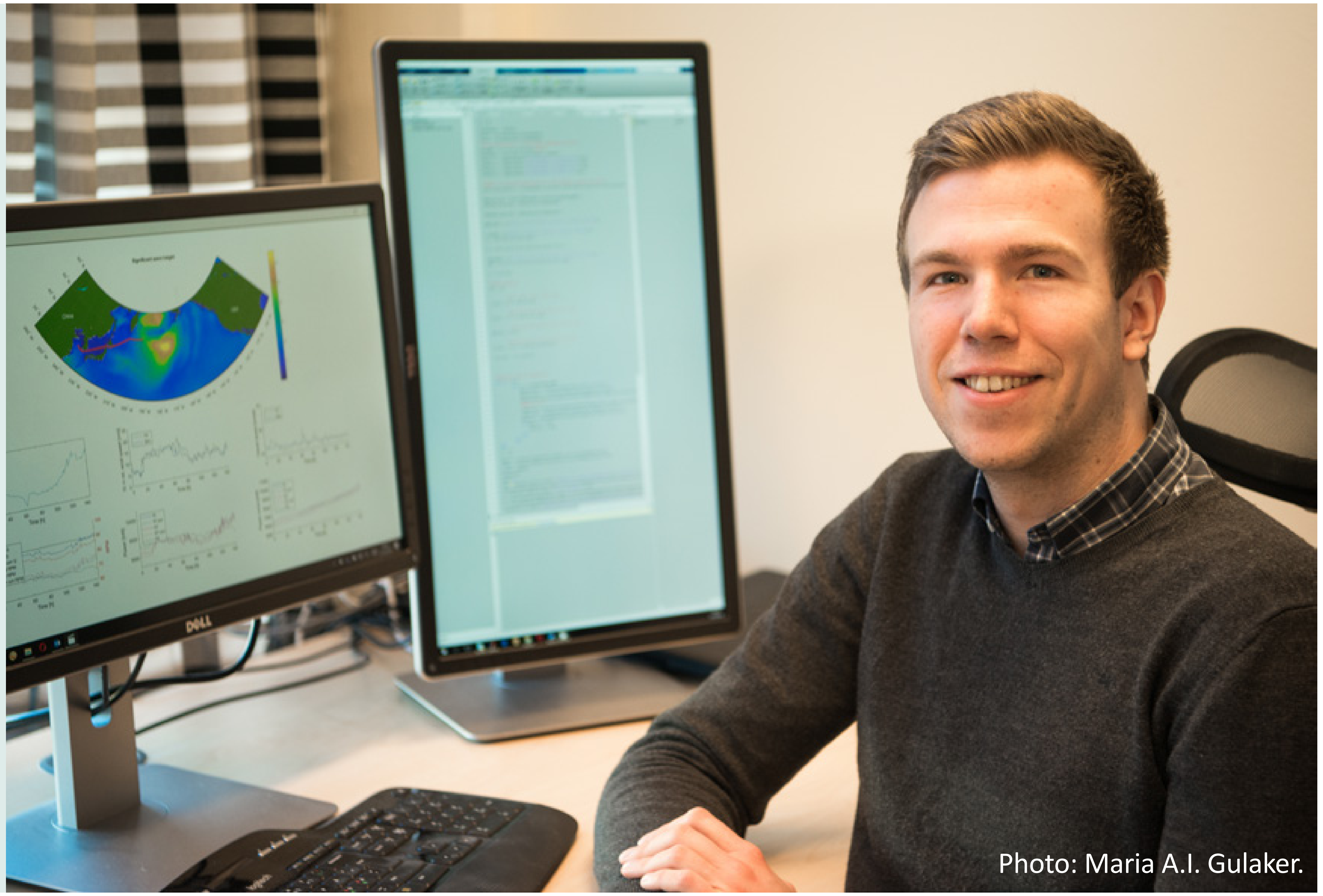


Photo: Maria A.I. Gulaker.

Research topics

The purpose of the PhD research is to provide knowledge regarding the validity of simulation models for application in ship design. The research will focus on how simulation is applied to virtually test designs in realistic conditions and operational scenarios. This includes benchmarking of simulation results and full-scale measurements to reveal important factors that influence the quality of simulation estimates.

Industrial goals

Knowledge that supports energy efficient design and operation of ships using simulation-based methods. The current research focuses on resistance, propulsion and fuel consumption of deep-sea vessels in transit.

Achievements

A validation study towards estimation of fuel consumption and operational profile using GYMIR was conducted in the last quarter of 2017. The methodology and results are presented in a conference paper submitted to the International Marine Design Conference in Helsinki June 2018. Further validation studies of the GYMIR workbench will be performed in 2018.

Supervisors

Main supervisor:

- Professor Bjørn Egil Asbjørnslett, NTNU IMT

Co-supervisors:

- Professor Sverre Steen, NTNU IMT
- Professor 2 Stein Ove Erikstad, IMT (FEDEM)
- Associate professor Eilif Pedersen, NTNU IMT

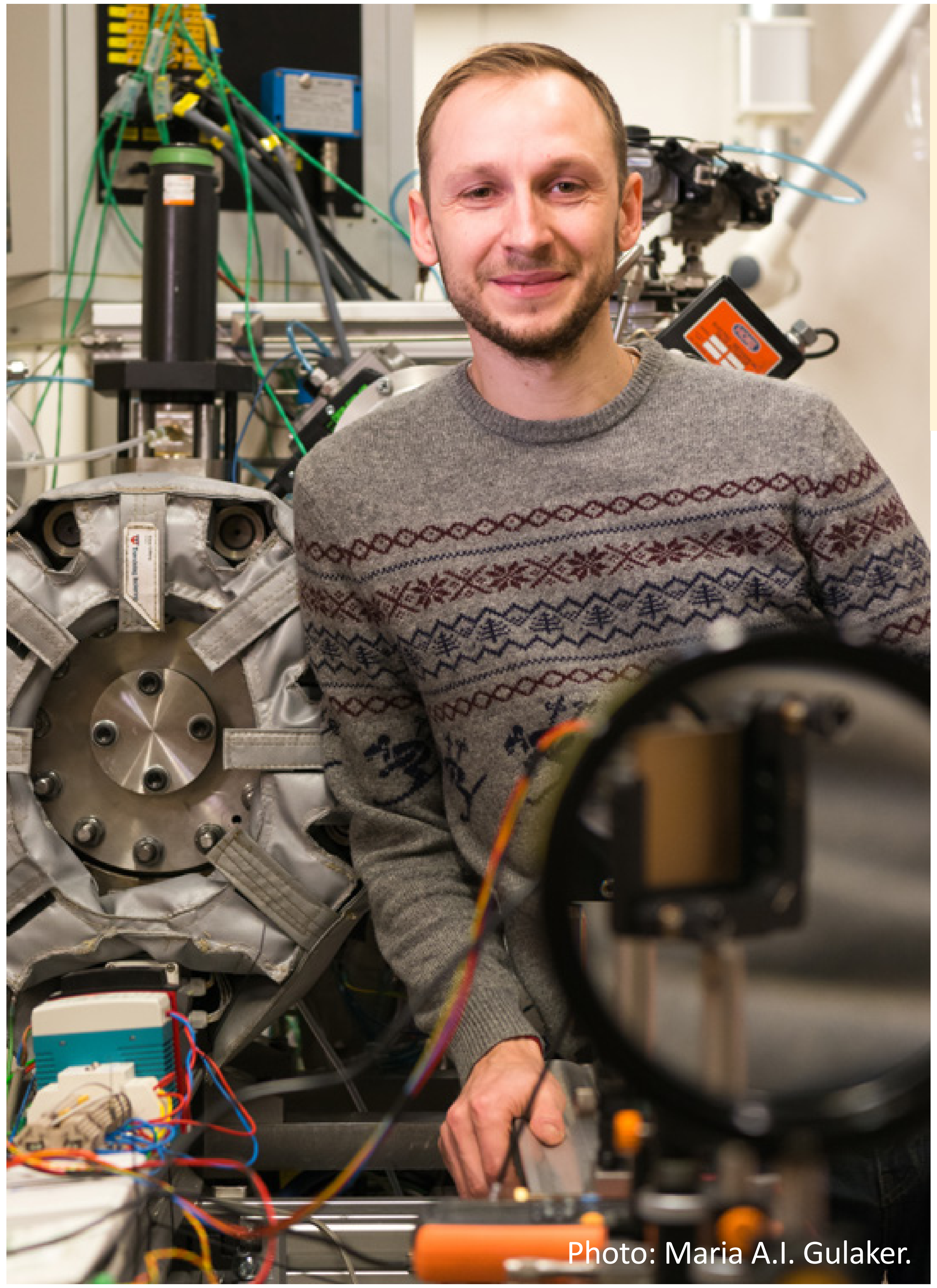


Photo: Maria A.I. Gulaker.

Vladimir Krivopolianskii

PhD student WP3 (2015–2018)

Development of a constant volume combustion rig for experimental investigation of combustion and emission characteristics of alternative fuels

Research topics

Environmental regulations to reduce emissions from ships are creating a strong impulse for the development of new technological and operational solutions. Utilization of alternative fuels such as biodiesel, natural gas and hydrogen instead of conventional fuels in marine engines can potentially reduce emissions and hence satisfy the environmental requirements.

For fundamental study of the emission from alternative fuels' combustion, this project is to develop an experimental setup that resembles a combustion chamber environment in a marine diesel/natural gas engine.

In order to ensure an application of non-intrusive measuring techniques, the experimental setup is equipped with optical windows for detail study of combustion phenomena. For case studies, the research on biodiesel and natural gas + hydrogen blends combustion was chosen.

Industrial goals:

To develop a facility and experimental research methods for testing the performance of marine engine injection valves and for investigation of combustion process of both liquid and gaseous fuels.

Supervisors

Supervisor:	Sergey Ushakov (IMT, NTNU)
Co-supervisor:	Eilif Pedersen (IMT, NTNU)

Jon Coll Mossige

PhD student WP2
(2017–2020)

Added resistance on ships due to hull roughness

Photo: Maria A.I. Gulaker.

Research topics

The research will initially be focused on a numerical investigation of roughness effects on the turbulent boundary layer for a flat plate. A challenge here is to find a parametrization for the roughness found on hulls in typical conditions. This includes everything from heavily fouled to freshly painted hulls.

Further research may include a study of the impact on the roughness effects by plate curvature and/or presence of waves, as well as an investigation of new coating designs in cooperation with JOTUN.

Industrial goal

- Improve prediction methods for power requirement and fuel consumption of full scale ships.
- Design of new hull coating technologies with better performance, both when it comes to resistance and anti-fouling capabilities.

Scientific questions

To which level do we understand the effect of roughness on fluid flowing past a wall?

Which parameters are necessary in order to describe the roughness on a typical hull plate?

What is the impact of flow perturbations and plate curvature on the added resistance due to roughness?

Cooperating company

JOTUN

Supervisors

Supervisor: Lars Erik Holmedal (NTNU)
Co-supervisor: Kourosh Koushan (NTNU, SINTEF)


Photo: Maria A.I. Gulaker.

Torstein Ingebrigtsen Bø

Postdoc WP3 (2015-2017)

Hybrid propulsion, integrating new power sources for marine power plants

Research topics

The purpose of the Postdoc is to provide models of marine electric power plants suitable for design and optimisation of propulsion systems. This also includes measurements of losses of real equipment in addition to control studies.

Industrial goals

The goal of the study is to establish models of the marine electric power plants. Today there exist multiple models for powerplants. However, their use case is often either to investigate dynamics or losses. The models should be complex enough to capture the most important dynamics of the system, while simple enough to be efficient in an early design phase. Loss models of marine power plants are either very complex (finite element method) or just a fixed efficiency. The aim of the development is to bridge the gap between these two model types.

Foreseen innovation

The models of the power plant can be useful in further design of marine power plants. It has been shown that using fixed efficiency of equipment is not sufficient for DP vessels, as the power demand is often very low. These models can therefore help further optimization of the powerplant for more economic and environmentally friendly operations.

Cooperation with industry partners

ABB has helped with testing of losses in the joint hybrid power lab, Rolls Royce has contributed with load profiles and models of components in marine power plants.

Main achievements / milepæler

- Models for marine power plants, including main losses
- Estimation of losses for supply vessel
- An MPC based controller for gas engines and batteries

Faculty / Supervisor

Associate professor Eilif Pedersen, NTNU IMT

Photo: SINTEF Ocean.

Lokukaluge Prasad Perera

Postdoc WP2/WP3 (2015–2017)

Data handling framework for ship performance and navigation monitoring

Summary of Postdoc project

L.P. Perera has developed a machine learning based data handling framework with various data analytics to overcome the respective challenges in ship performance and navigation monitoring. There are various industrial challenges encountered in large-scale data handling situations among vessels and shore based data centers.

The proposed data handling framework consists of pre and post-process sections as onboard and onshore applications, respectively. The pre-process as a part of ship IoT consists of the data analytics with data anomaly detection and parameter reduction/data anomaly compression facilitated by data driven models, i.e. digital models.

The pre-processed data communicate through onboard data transmitters in much smaller improved data sets and that are obtained by shore based data centers through data receivers. The post-process as a part of onshore data centers consists of the data analytics with parameter expansion/data anomaly recovery, integrity verification & regression and data visualization & decision support facilitated by the same digital models.

These data analytics has special features of self-learning (i.e. data clusters and the structure of each data cluster), self-cleaning (i.e. sensor and DAQ fault removal and compression, data recovery, data regression & integrity verification), self-compression & expansion (i.e. parameter reduction and expansion).

Furthermore, that has a multi-purpose structure that can be used for both ship energy efficiency and system reliability applications.

Photo: Pål Leraand.

Renato Skejic

Postdoc WP2 (2016–2018)

Marine Engineering and Ships/Offshore Structures
Hydrodynamics and Hydrostatics

Research goal and strategy

Post doc Renato Skejic is working with development of medium-fidelity computational methods for added resistance due to waves. This means potential flow methods that are less complicated, faster and more robust than full 3-D non-linear panel methods while still being more accurate than the current linear potential flow methods implemented in ShipX and applied in GYMIR.

The methods he is aiming at will be computationally fast, but will require input of 3-D hull geometry. The deliverables are expected to be in terms of scientific paper(s) and computer implementation(s) of the method(s). Final implementation and integration with (for instance) ShipX and GYMIR will be outside the scope of the post doc project.

Ongoing research

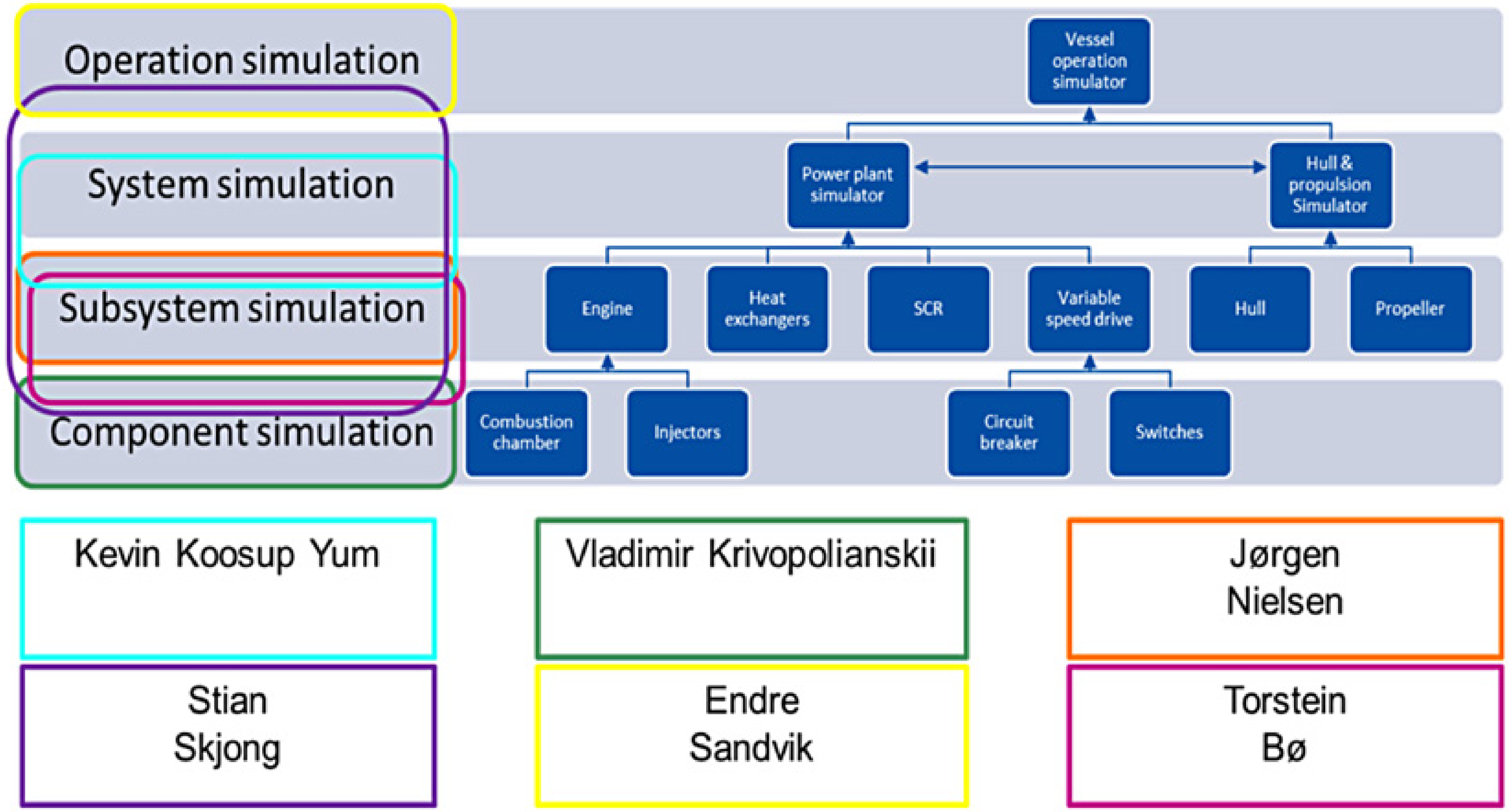
The ships behavior and their operational patterns in a seaway are strongly affected by the presence of the added resistance in a seaway. Therefore, in order to ensure the optimized and economically justified short, medium and/or long time duration voyages of the ship in the realistic irregular wave field scenarios, the added resistance needs to be investigated from both, the theoretical and/or experimental point of view.

Present work, related to the investigation of the added resistance in waves, accounts for the several, so called, medium-fidelity theoretical methods, which are capable for the prediction of the mentioned quantity. The methods, having the medium level of complexity and being satisfactory robust and fast, are based on the pragmatic theoretical derivations. They, in the same time, are satisfying requirement concerning the accuracy within common engineering practice. This in turn makes the medium-fidelity methods one of the best candidates for the simulator environment when the investigation of the ship optimized operational profile in a seaway is required.

The developed medium-fidelity methods for the prediction of the added resistance in waves are employed on the several distinctive ship hull forms with the significantly different block coefficients. This is done in order to exemplify capabilities of the developed methods in respect to the investigated ship hull forms and their corresponding experimental data. Finally, the applicability of the medium-fidelity methods is discussed based on the requirements imposed by the parties involved in investigation of the optimized ships operational profiles in a seaway.

COLLABORATIVE RESEARCH ACTIVITY

The work on simulation models and tools in WP3 and WP4 gives a good example of interdiscipline collaboration. The researches form a unique group covering all the stages of simulation hierarchy, from single components, to system, and up to operational level. This approach leads to work efficiency and more valuable results.



This, in terms of publications, but also routines and practices that can be later adopted and used within maritime industry.

The project of Vladimir Krivopolianskii (NTNU/SFI, PhD student WP3) is dedicated to simulation of injection and combustion processes of alternative marine fuels. Jørgen Nielsen (NTNU/SFI, PhD student WP3/4) uses simulation approach to model the work of waste heat recovery systems and emission abatement systems, while Torstein Bø (NTNU/SFI, Postdoc WP3) simulates the potential hybrid systems (with emphasis on energy conversion efficiency) for marine application. Kevin Koosup Yum (Sintef Ocean/SFI, Research scientist WP3) applies his own simulation model of ship's power plant, which can be improved based on the findings of the other group members, to perform simulation-based concept design, i.e. to find the most effective concept of vessel for certain application.

Stian Skjong (NTNU, PhD student project ViProMa) and his co-simulation approach allows to link together various models of different fidelity levels and run them together. At the same time co-simulation can be coupled to the operation-oriented simulation software, where the performance of a vessel in certain real operational conditions can be simulated and optimized. This is done by Endre Sandvik (NTNU/SFI, PhD student WP4), using GYMIR software created by SINTEF Ocean (WP4).

SMART MARITIME

PEOPLE

Photo: Norwegian Electric Systems.

INDUSTRY NETWORK (BY COMPANY)

ABB
Børre Gundersen
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Matko Basiric

Bergen Engines
Jan Eikefet
Leif Arne Skarbø*
Erlend Vaktskjold

DNV GL
Hendrik Brinks*
Christos Chryssakis
Hans Anton Tvete

Grieg Star
Roar Fanebust
Jan Øivind Svardal*
Henry Svendsen
Svenn Sørstrand

Havyard Group
Daniel Aaro
Kay Lorgen
Arve Nedreberg
Ole Rorhus
Kristian V. Steinsvik*
Rolf Arild Topphol
Kåre Nerland

Jotun
Lennard Bosh
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Stein Kjølberg
Andreas Krapp
Geir Axel Oftedahl

Kristian Gerhard Jebsen Skipsrederi
Jan Berntzen
Ole-Johan Haahjem*
Øyvind Monsen

Kystrederiene
Tor Arne Borge*
Ivar Ulvan

Norwegian Electric Systems
Frithjof Hustig*
Stein Ruben Larsen
Ottar Skjervheim

Rolls-Royce Marine
Martijn de Jongh
Hans Martin Hjørungnes
Per Ingeberg*
Kristen Jomås
Sverre Torben
Leif Vartdal
Bjørnar Vik

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Tor Christian Sletner*
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Kjell Morten Urke

Wallenius Wilhelmsen Logistics
Lars Dessen

Wärtsilä Moss
Sigurd Jenssen

Road Fanabust
Coordinator of Technical Advisory Committee

RESEARCH TEAM

SINTEF Ocean / NTNU employees

Name	Company	Main Focus area	
Anna L. Ringvold	NTNU	Life-cycle assessment	WP5, WP1
Anders H. Strømman	NTNU	Environmental assessment	WP5 leader, WP1
Anders Valland	SINTEF Ocean	Hybrid propulsion	Deputy director, WP3
S. Anders Alterskjær	SINTEF Ocean	Hull and propeller hydrodynamics	WP2
Andrew Ross	SINTEF Ocean	Hydrodynamics	WP2
Bjørn Egil Asbjørnslett	NTNU	Feasibility studies	WP1
Dag Stenersen	SINTEF Ocean	Hybrid propulsion	WP3
Dariusz Fathi	SINTEF Ocean	Data simulations and optimization	WP2, WP4
Elizabeth Lindstad	SINTEF Ocean	Feasibility studies	WP1 leader, WP5
Eilif Pedersen	NTNU	Power systems and fuel	WP3
Evert Bouman	NTNU	Environmental assessment	WP5
Helene Muri	NTNU	Climate and environmental impact	WP5
Henning Borgen	SINTEF Ålesund	Simulation based design	
Håvard Nesse	SINTEF Ocean	System development	WP4
Ingebrigt Valberg	SINTEF Ocean	Power systems and fuel	WP3
Jon Dæhlen	SINTEF Ocean	Simulation-based concept design	WP4
Kevin Koosup Yum	SINTEF Ocean	Simulation, Machinery	WP3,
Kourosh Koushan	SINTEF Ocean	Hull and propeller hydrodynamics	WP2
Martin Rindarøy	SINTEF Ocean	Data simulations and optimization	WP4
Ole Thonstad	SINTEF Ocean	Full scale data harvesting	WP3
Per Magne Einang	SINTEF Ocean	Power systems and fuel	Centre director, WP3
Sergey Ushakov	NTNU	Exhaust emissions	WP3 leader
Sverre Steen	NTNU	Hull and propeller hydrodynamics	WP2 leader
Trond Johnsen	SINTEF Ocean	Data simulations and optimization	WP4 leader
Vilmar Æsøy	NTNU Ålesund	Power systems and fuel	WP3

SINTEF OCEAN


S. Anders Alterskjær


Anders Valland


Andrew Ross


Dag Stenersen


Dariusz Fathi


Elizabeth Lindstad


Håvard H. Nesse


Ingebrigt Valberg


Jon Dæhlen


Kevin Koosup Yum


Kourosh Koushan


Martin Rindarøy


Trond Johnsen


Ole Thonstad


Per Magne Einang


Henning Borgen
SINTEF Ålesund

NTNU


Anna Ringvold


Anders H. Strømman


Bjørn Egil Asbjørnslett


Evert Bouman


Helene Muri


Eilif Pedersen


Sverre Steen


Sergey Ushakov


Vilmar Æsøy **NTNU Ålesund**

Elfrida. Batteries and power electronic from Siemens. Photo: Siemens AS.

PHD STUDENTS AND POSTDOCTORAL RESEARCHERS

Name	Funding source	NAL	Period	Topic
Postdoctoral researchers				
Lokukaluge Prasad Perera	SFI Smart Maritime WP2/3	LK	2015–2017	Data handling and analysis
Torstein Ingebrigtsen Bø	SFI Smart Maritime WP3	NO	2015–2017	Hybrid propulsion
Renato Skejic	SFI Smart Maritime WP2	HR	2016–2018	Computation of added resistance due to waves
Erik Bøchmann	KPN LEEDS	NO	2015–2017	Hydrodynamic
PhD students				
Jon Coll Mossige	SFI Smart Maritime WP2	NO	2017–2020	Hydrodynamics
John Martin Godø	SFI Smart Maritime WP2	NO	2015–2020**	Hydrodynamics
Jørgen B. Nielsen	SFI Smart Maritime WP3/4	NO	2015–2018	System simulation
Vladimir Krivopolianskii	SFI Smart Maritime WP3	UA	2015–2018	Fuel injection and combustion
Endre Sandvik	SFI Smart Maritime WP4	NO	2016–2019	Simulation Based Design of Ships
Sadi Tavakoli	NTNU*	IR	2017–2020	Marine machinery
Simone Saettone	NTNU*	IT	2017–2020	Hydrodyna Simulation based designmics
Mahdi Ghane	NTNU		2013–2017	Dynamic Modelling; Emphasis on the Behavior in Fault Conditions
Stian Sjong	KPN ViProma	NO	2013–2017	System Simulation
Øyvind Øksnes Dahlheim	Rolls-Royce UTC	NO	2015–2018	Hydrodynamics
Anna Swider	Rolls-Royce Ind. PhD	PL	2015–2018	Hydrodynamics
Sabah Alwan	KPN LEEDS	AU	2013–2017	Simulation based design
Dig Vijay Singh	KPN LEEDS	UK	2012–2016	Machinery
Bhushan Taskar	KPN LEEDS	IN	2013–2016	Hydrodynamics
Jarle Kramer	KPN LEEDS	NO	2013–2018	Hydrodynamics

* *Double Doctorate Degree (cotutelle) agreement between NTNU and DTU (Technical University of Denmark)*

** *including a 2 year leave for commercialization of Flying Foil concept.*

SMART MARITIME PHD STUDENTS AND POSTDOCS

Torstein Ingebrigtsen Bø
NTNU

John Martin Godø
NTNU

Vladimir Krivopolianskii
NTNU

Jon C. Mossige
NTNU

Jørgen Nielsen
NTNU

Lokukaluge Prasad Perera
SINTEF Ocean

Endre Sandvik
NTNU

Renato Skejic
SINTEF OCEAN

MSc THESIS WITHIN SMART MARITIME

MSc students	University, Department	Year	Topic MSc thesis
Mats William Snåre **Jon Halfdanarson**	NTNU, Energy and Process Engineering	2015	Implementation and application of an integrated framework for economic and environmental assessment of maritime transport vessels
Jørgen Rørvik	NTNU, Marine Technology	2016	Application of Inviscid Flow CFD for prediction of Motions and Added Resistance of Ships
Haakon Utby	NTNU, Marine Technology	2016	Hydrodynamic optimization of bulk and tank ship hulls
Anna Karina Magnussen	NTNU, Marine Technology	2017	Rational calculation of sea margin
Jens Christoffer Gjølme	NTNU, Marine Technology	2017	Estimation of Speed Loss due to Current, Wind and Waves
Sigbjørn Wiik	NTNU, Marine Technology	2017	Voluntary speed loss
Fredrik Gyberg	NTNU, Marine Technology	2017	Design, modelling and control of a generic crane for marine application
Thomas Haraldsen Evang	NTNU, Marine Technology	2017	Marine Crane Dynamics Lab - Modelling and experimental validation
Jan Olav Øksnes	NTNU, Marine Technology	2017	Regeneration in Crane Operation
Anna Ringvold	NTNU, Industrial Ecology	2017	Prospective life cycle assessment of container shipping
Mafalda Silva	NTNU, Industrial Ecology	2017	Life cycle assessment of marine fuel production
Martin Øksdal Bakke **Peter Slinning Tenfjord**	NTNU, Marine Technology	2017	Simulation-Based Analysis of Vessel Performance During Sailing - Describing a simulation platform applied in early stage ship design
Andrea Aarseth Langli	NTNU, Marine Technology	2017	Exhaust Gas Cleaning Systems - Selecting the Best EGCS Option Using the Analytic Hierarchy Process and Cost Benefit Analysis
Jon Hovem Leonhardsen	NTNU, Marine Technology	2017	Estimation of Fuel Savings from Rapidly Reconfigurable Bulbous Bows Exemplifying the Value of Agility in Marine Systems Design
Jon-Erik Hvidsten Remme	NTNU, Marine Technology	2017	Multivariate Data Analysis in Conceptual Vessel Design – A Study of Offshore Construction Vessels

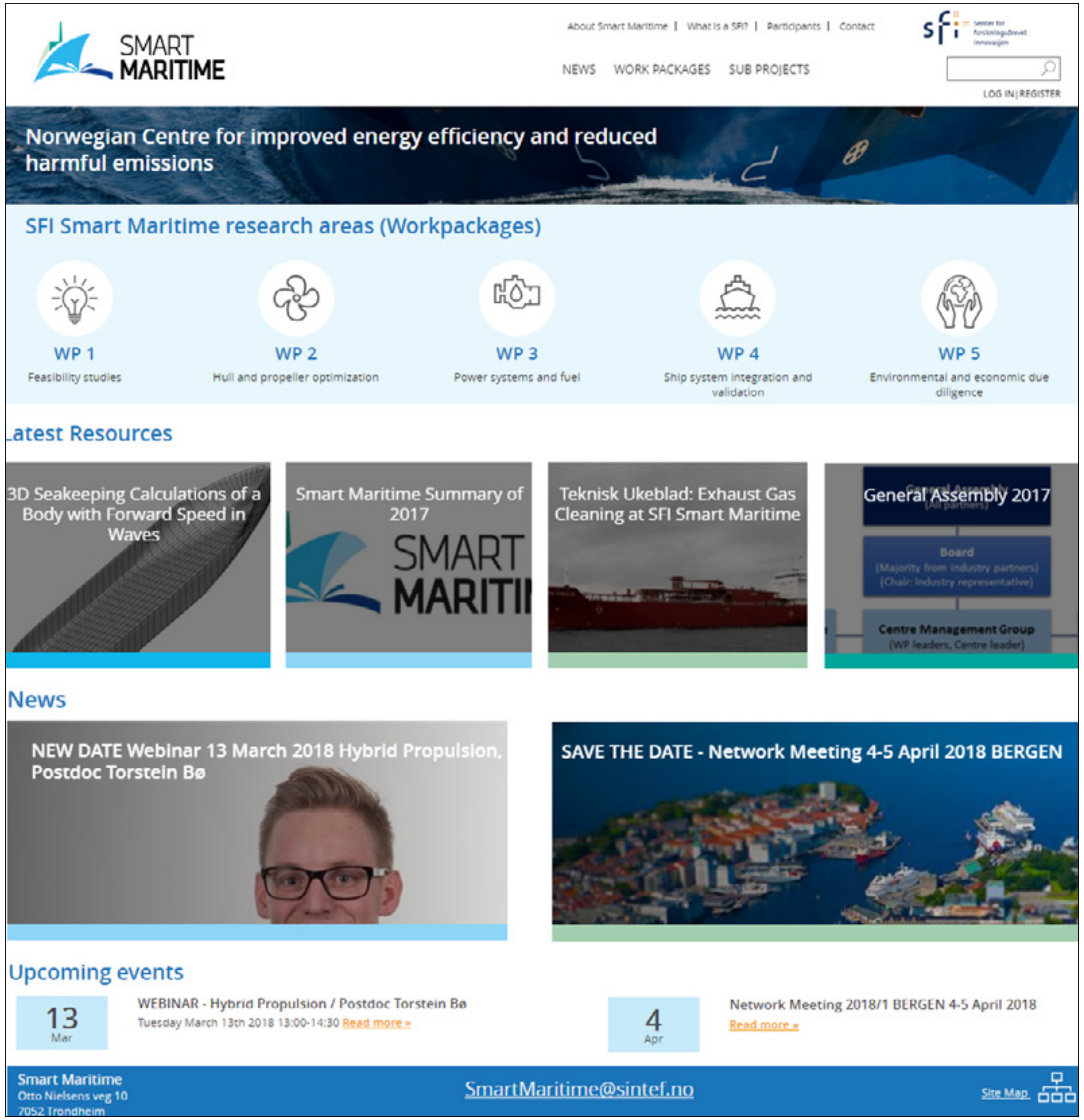
COMMUNICATION AND DISSEMINATION

Clipper Quito. Photo: Solvang.

COMMUNICATION

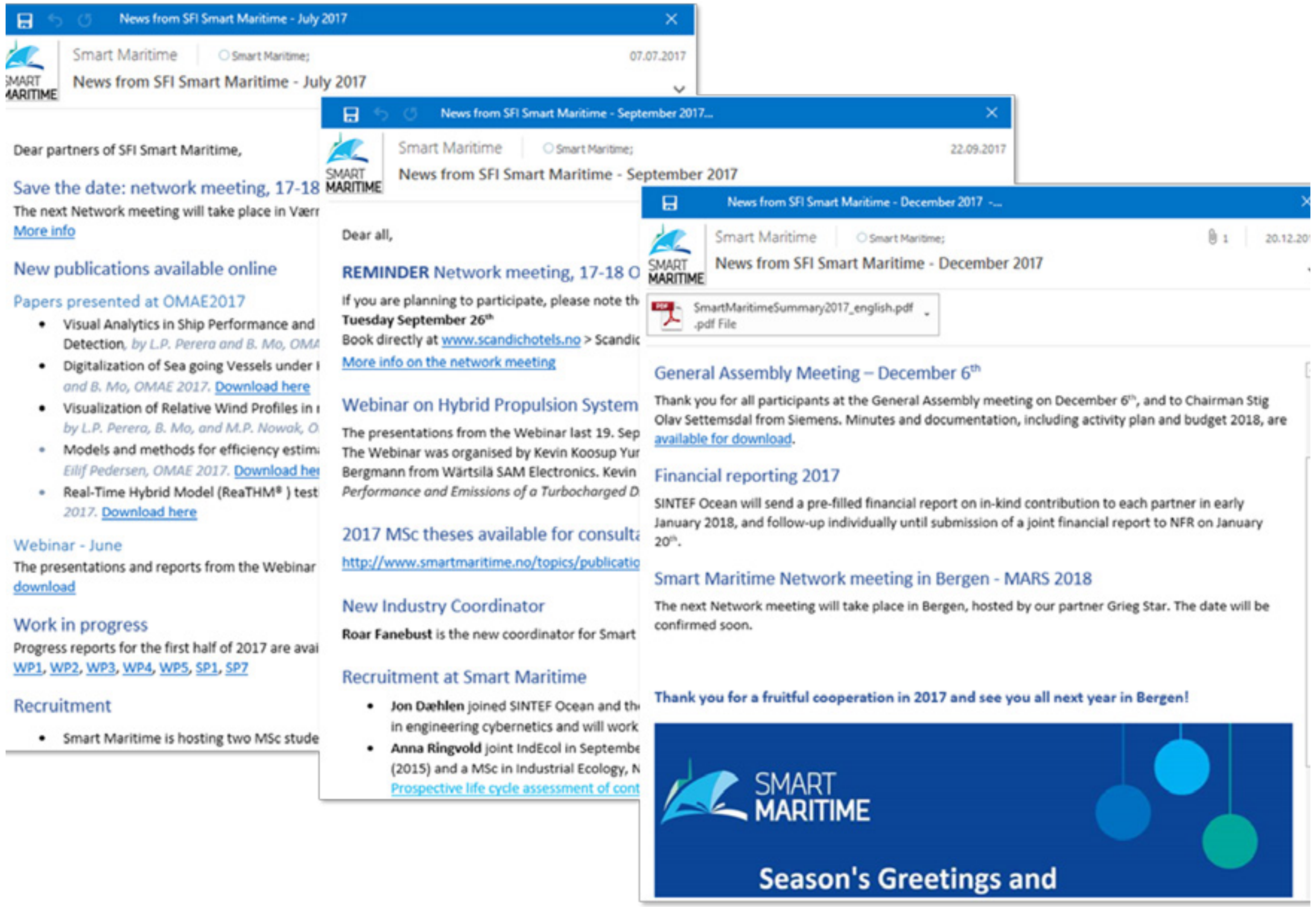
Website

www.smartmaritime.no is used for public information about the Centre and for dissemination of publications and presentation material to Smart Maritime partners through a members-only area. News and events are also administrated on the website.



Newsletters

Regular e-mail newletters are sent to Smart Maritime participants, with information about the research activity, main results, links to publications and information on the website, and upcoming events.



Webinars

Smart Maritime offers Webinars that contribute to more scientific discussion between research team and industry partners and a wider network.

Two Webinars were held in 2017.

- **Hybrid Propulsion System** - Design and Application with PTI/PTO solutions, lead by Kevin Koosup Yum, September 19th.
- **LNG-fuelled vessel**, lead by Dag Stenersen and Per Magne Einang, June 21st

PUBLICATIONS AND REPRESENTATIONS

Scientific Journal Papers

Lindstad, Elizabeth; Rehn, Carl Fredrik; Eskeland, Gunnar **Sulphur Abatement Globally in Maritime Shipping.** *Transporta-tion Research Part D: Transport and Environment 2017 (1361–9209) Vol. 57, s. 303–313.*

Perera, Lokukaluge Prasad; Mo, Brage **Machine Learning based Data Handling Framework for Ship Energy Efficiency.** *IEEE Transactions on Vehicular Technology 2017 (0018–9545) Vol. 66 (10), s. 8659–8666.*

Pascoal, R; Perera, Lokukaluge Prasad; Guedes Soares, Carlos **Estimation of Directional Sea Spectra from Ship Motions in Sea Trials.** *Ocean Engineering 2017 (0029–8018).*

Lindstad, Haakon Elizabeth; Eskeland, Gunnar; Rialland, Agathe Isabelle **Batteries in offshore support vessels – Pollution, climate impact and economics.**
Transportation Research Part D: Transport and Environment 2017 (1361–9209) Vol. 50, s. 409–417.

Perera, Lokukaluge Prasad; Mo, Brage **Marine Engine-Centered Data Analytics for Ship Performance Moni-toring.** *Journal of Offshore Mechanics and Arctic Engineering 2017 (0892–7219) Vol. 139 (2).*

Bouman, Evert; Lindstad, Haakon Elizabeth; Rialland, Agathe Isabelle; Strømman, Anders Hammer **State-of-the-art technologies, measures, and potential for reducing GHG emissions from shipping – A review.** *Transportation Research Part D: Transport and Environment 2017 (1361–9209) Vol. 52, s. 408–421.*

Article in business/trade/industry journal

Lindstad, Elizabeth **Cost factors.** *Bunkerspot 2017 (1741-6981) Vol. July, s. 68–70.*
Lindstad, Haakon Elizabeth **Shipping needs 85% GHG cuts by 2050 if seen as a nation.**
TradeWinds 2017 Vol. 19 mai, s. 32–32.

Discussion paper

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STATEMENT OF ACCOUNTS 2017

	Funding		Cost	
Research council	14 021	(50 %)		
The Host Institution (SINTEF ocean)	2 097	(8 %)	11 65	(42 %)
Research Partners*	3 367	(12 %)	9 590	(35 %)
Industry partners	8 282	(30 %)	6 083	(22 %)
Equipment			443	(1 %)
Total NOK ‘000	27 767		27 767	

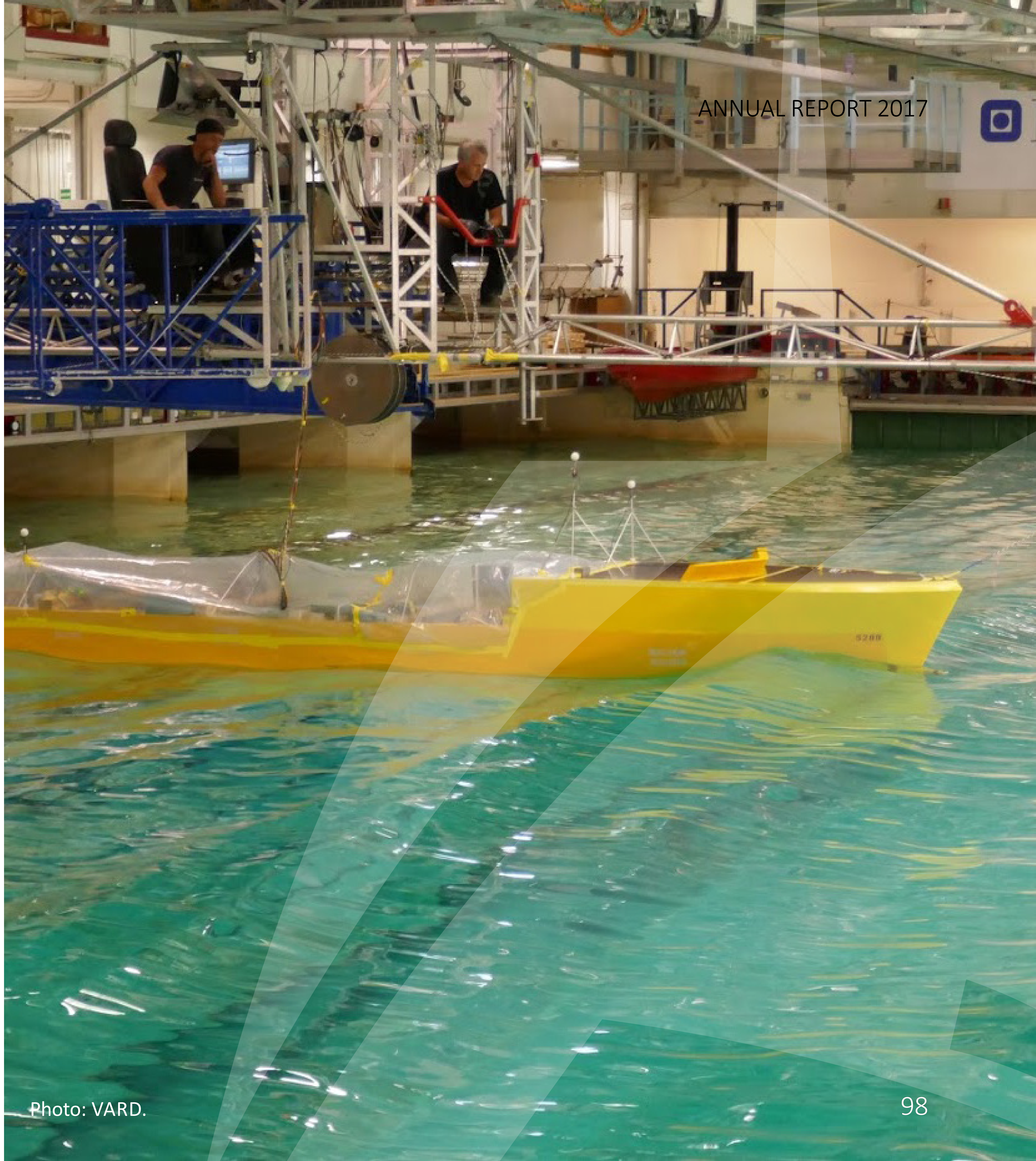

Photo: VARD.

SMART MARITIME

SMART MARITIME IN BRIEF

- Norwegian centre for improved energy efficiency and reduced harmful emissions from the maritime sector
- Centre for research-based innovation (SFI) granted by the research council (SFI-iii)
- Main goals:
  - Improve energy efficiency
  - Reduce harmful emissions
  - Strengthen the competitiveness of the norwegian maritime industry
- 30 research scientists
- 60 industry professionals
- 10 laboratories
- Duration: 2015–2023
- Budget: 24 mnok/year
- Financing:
  - 50 % research council
  - 25 % industry partners
  - 25 % research partners

Photo: DNV GL.


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SMART MARITIME
ANNUAL REPORT 2017
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